ECMO
Past, Present and Future

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ECMO System

Types of mechanical circulatory support

- **Impaired cardiac function**
  - ***Ventricular assist device (VAD)***
  - ***Extracorporeal membrane oxygenation (ECMO)***
  - ***Intra-aortic balloon counter pulsation (IABP)***
  - ***Conventional CPB circuit***
- **Impaired cardiopulmonary function**
  - ***ECMO***
- **Impaired pulmonary function**
  - ***Veno-venous ECMO***

Physiological fundamental of circulatory support

Cardiac function

- Adequate cardiac output
  - Preload
  - Afterload
  - Myocardial contraction
  - Heart rate and rhythm

Pulmonary function

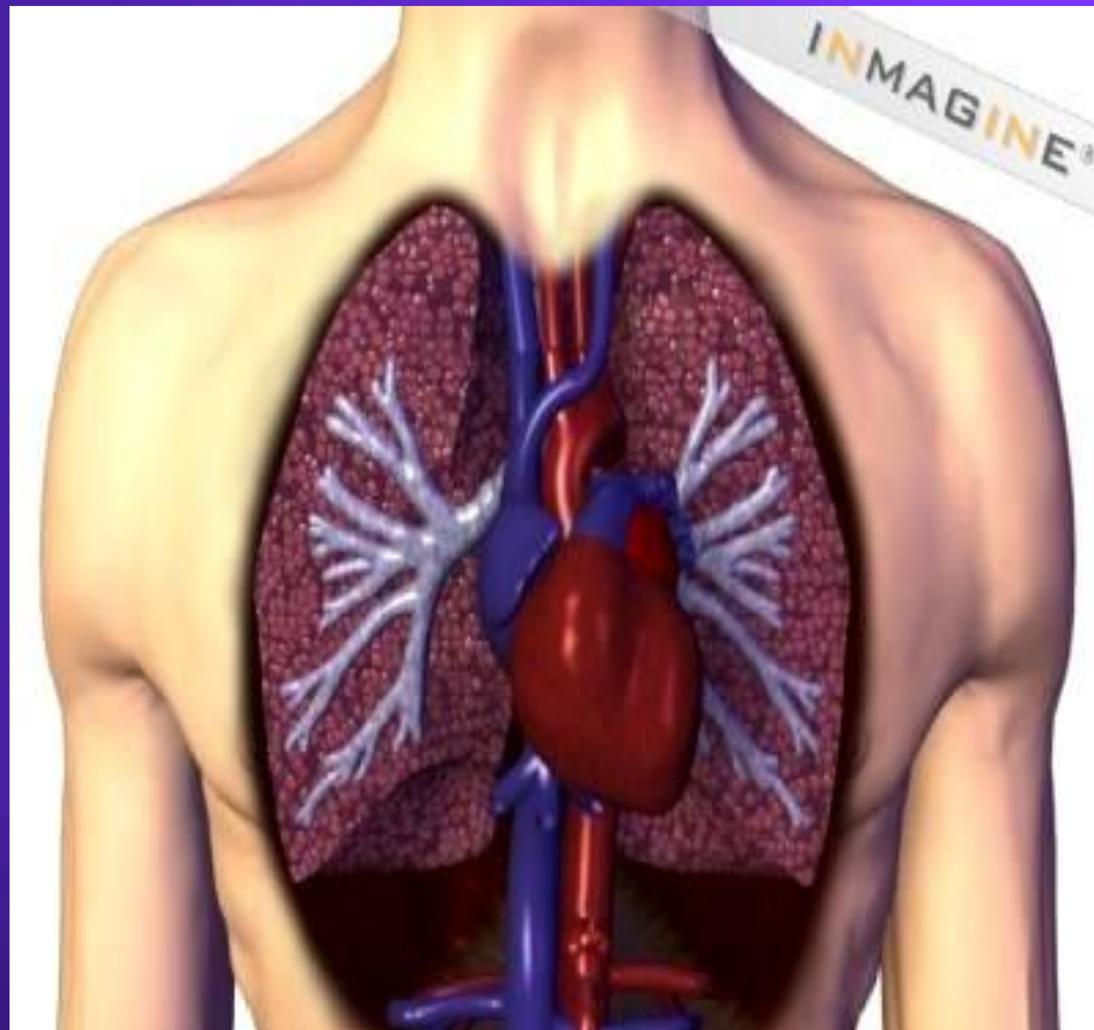
- Lung mechanics
- Gas exchange

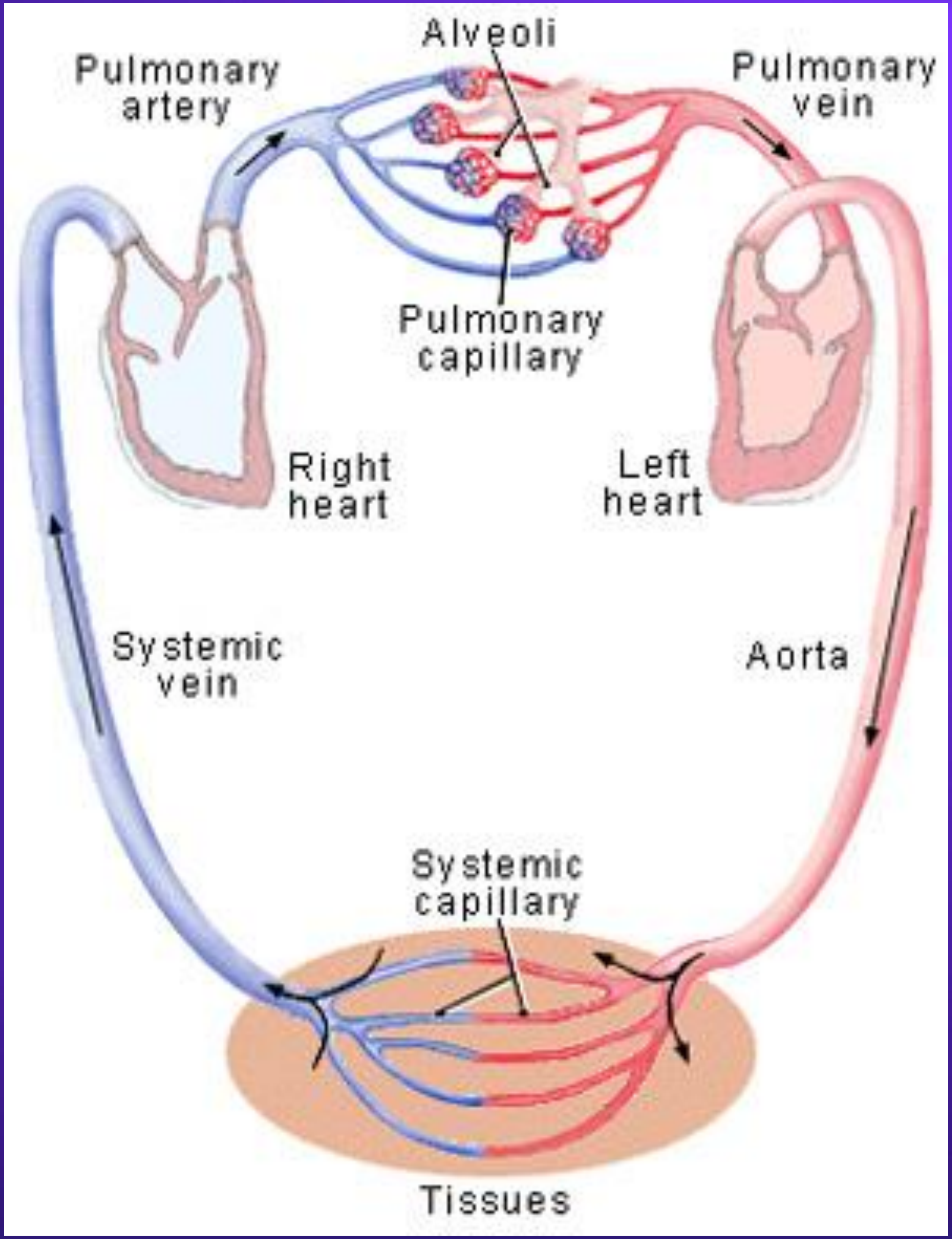
ECMO

Extracorporeal membrane oxygenation

- ECMO is temporary support of heart and lung function by partial cardiopulmonary bypass (up to 75 % of cardiac output). It is used for patients who have reversible cardiopulmonary failure from pulmonary, cardiac or other diseases.

Cardiopulmonary function




Alveoli
Pulmonary artery
Pulmonary vein
Pulmonary capillary
Right heart
Left heart
Systemic vein
Aorta
Systemic capillary
Tissues

Principle of ECMO

Veno-venous

1. object to pre-oxygenate blood before the lungs
2. no reduction in the pulmonary hypertension
3. provide no circulatory support

Veno-arterial

1. provides total cardiopulmonary support
2. rest the lung

ECMO indications

- After cardiac surgery, unable to wean off CPB
- Acute MI with cardiogenic shock
- Heart failure after transplantation due to graft rejection
- Respiratory distress syndrome
- Persistent pulmonary arterial hypertension of the neonate
- Congenital diaphragmatic hernia
- Sepsis
- Acute respiratory insufficiency
  - in pts. receiving at least 48 hours of optimal conventional ventilatory therapy with no improvement in pulmonary function
  - due to a viral or bacterial pneumonia, aspiration pneumonia, respiratory burns
  - diagnosis must be reversible within 14 days

ECMO indications

- ***Refractory failing circulation***
- ***Post CPR***
- ***Severe sepsis***
- ***Respiratory failure***
- ***Bridge to transplant***
- ***Bridge to bridge***
- ***Bridge to recovery***

ECMO indications

- Oxygenation index (OI): if > 40 predicts 80 % mortality without ECMO

$$\frac{MPaw.FiO2.100}{PO2(mmHg)}$$

- MPaw

$$\frac{(Paw.Ti)+(PEEP.Te)}{Ti+Te}$$

Neonatal ECMO
Inclusion criteria

- Gestational age > 35 weeks
- Birth weight > 2000 gm
- No bleeding abnormalities
- No major intracerebral haemorrhage
- No major congenital chromosomal defects
- Mechanical ventilation < 8-10 days
- No irreversible cardiopulmonary disease
- Reversible lung disease

Neonatal ECMO
Inclusion criteria

- Failure of maximal medical therapy
- OI > 40 for 3 hours
- Normal echocardiography

ECMO contra-indications

- Patients with irreversible conditions
- Chronic pulmonary disease
- Bleeding problems
- Documented irreversible brain damage
- Progressively degenerative systemic disease

Decision to Institute ECMO

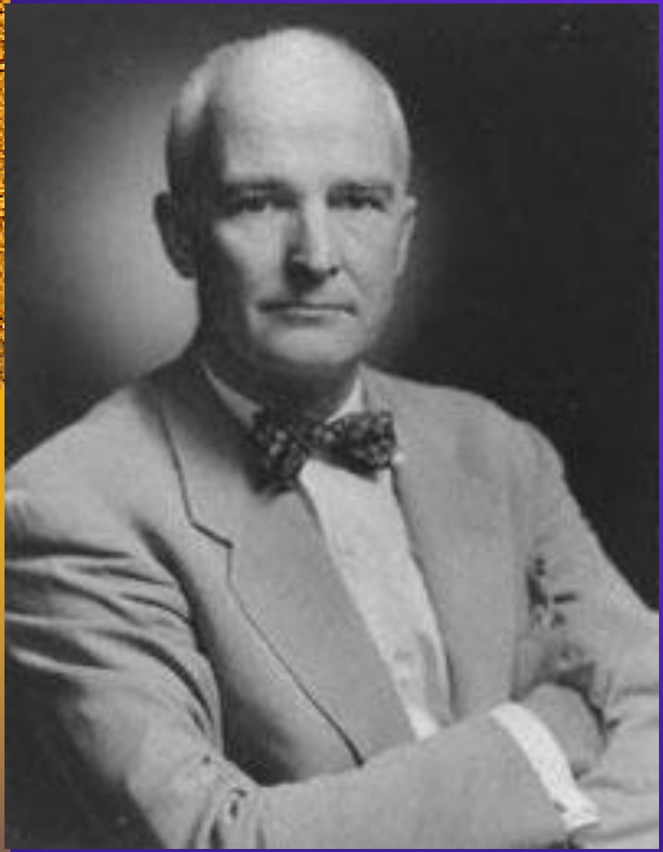
- Several considerations must be weighed:
  - Likelihood of organ recovery.: only appropriate if disease process is reversible with therapy and rest on ECMO
  - Cardiac recovery: to either wait for further cardiac recovery to allow implant of device (LVAD) or to list for transplantation.
  - Disseminated malignancy
  - Advanced age
  - Graft vs. host disease
  - Known severe brain injury
  - Unwitnessed cardiac arrest or cardiac arrest of prolonged duration.
  - Technical contraindications to consider: aortic dissection or aortic incompetence

THE BEGINNING

Evolution

- 1916 Jay McLean discovered heparin
- 1953 John H Gibbons Jr and his first heart-lung machine
- 1954 C Walton Lillihei and controlled-cross circulation – first biological extracorporeal oxygenation
- 1970, Baffes et al reported successful use of ECMO in infants CHD after undergoing cardiac surgery

John H Gibbon and his heart-lung machine



C Walton Lillehei and controlled cross circulation for open heart surgery

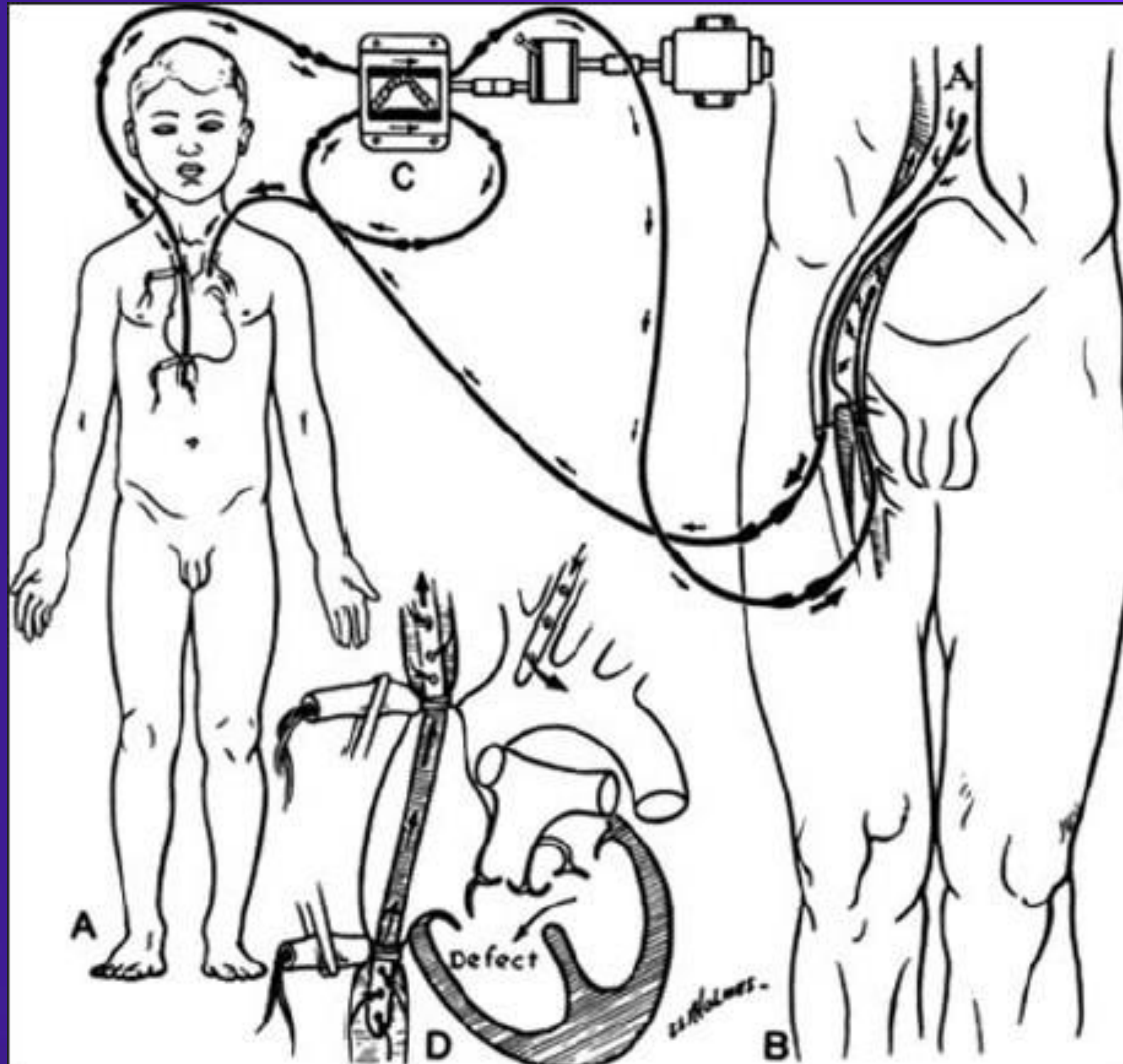
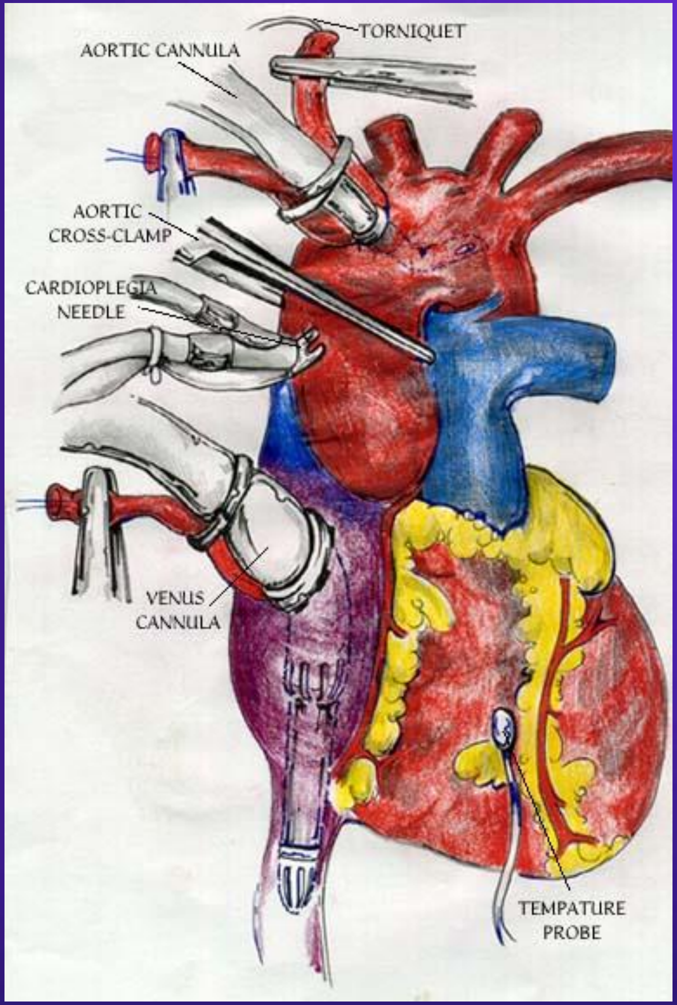
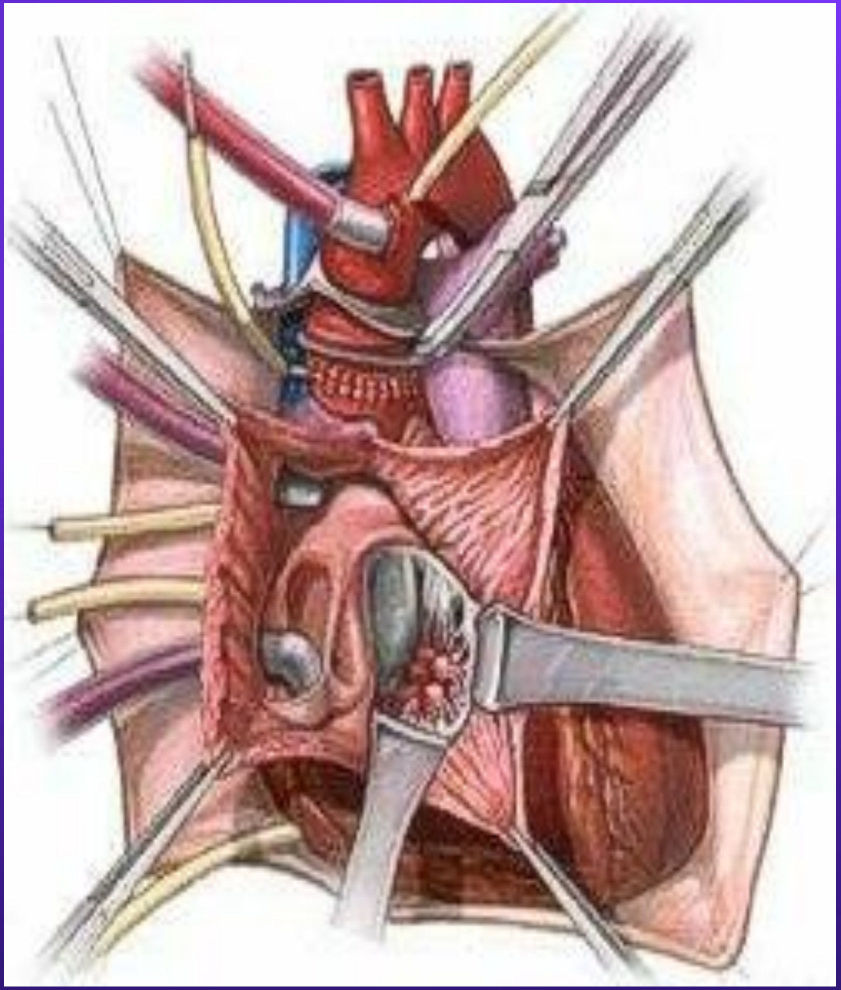
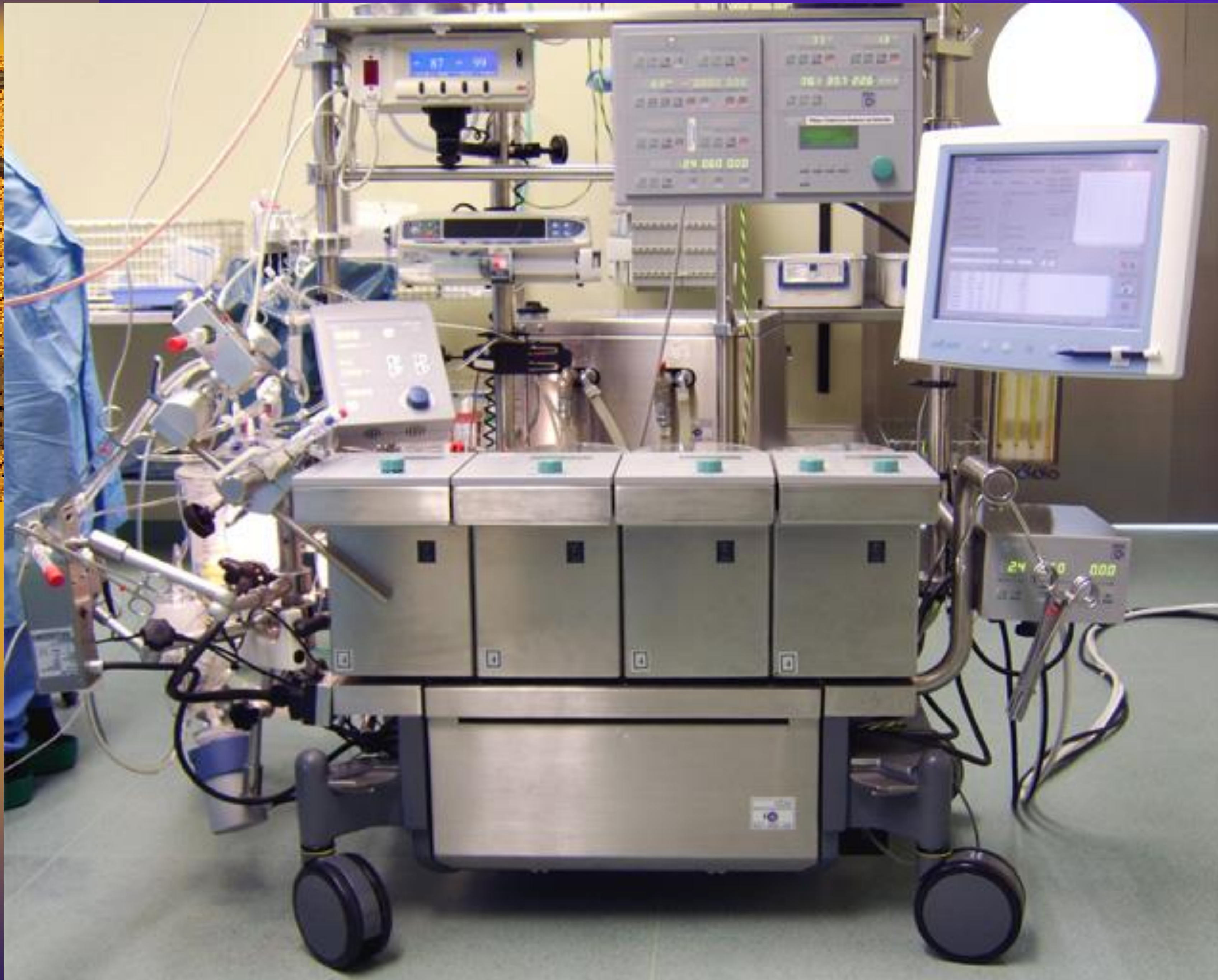


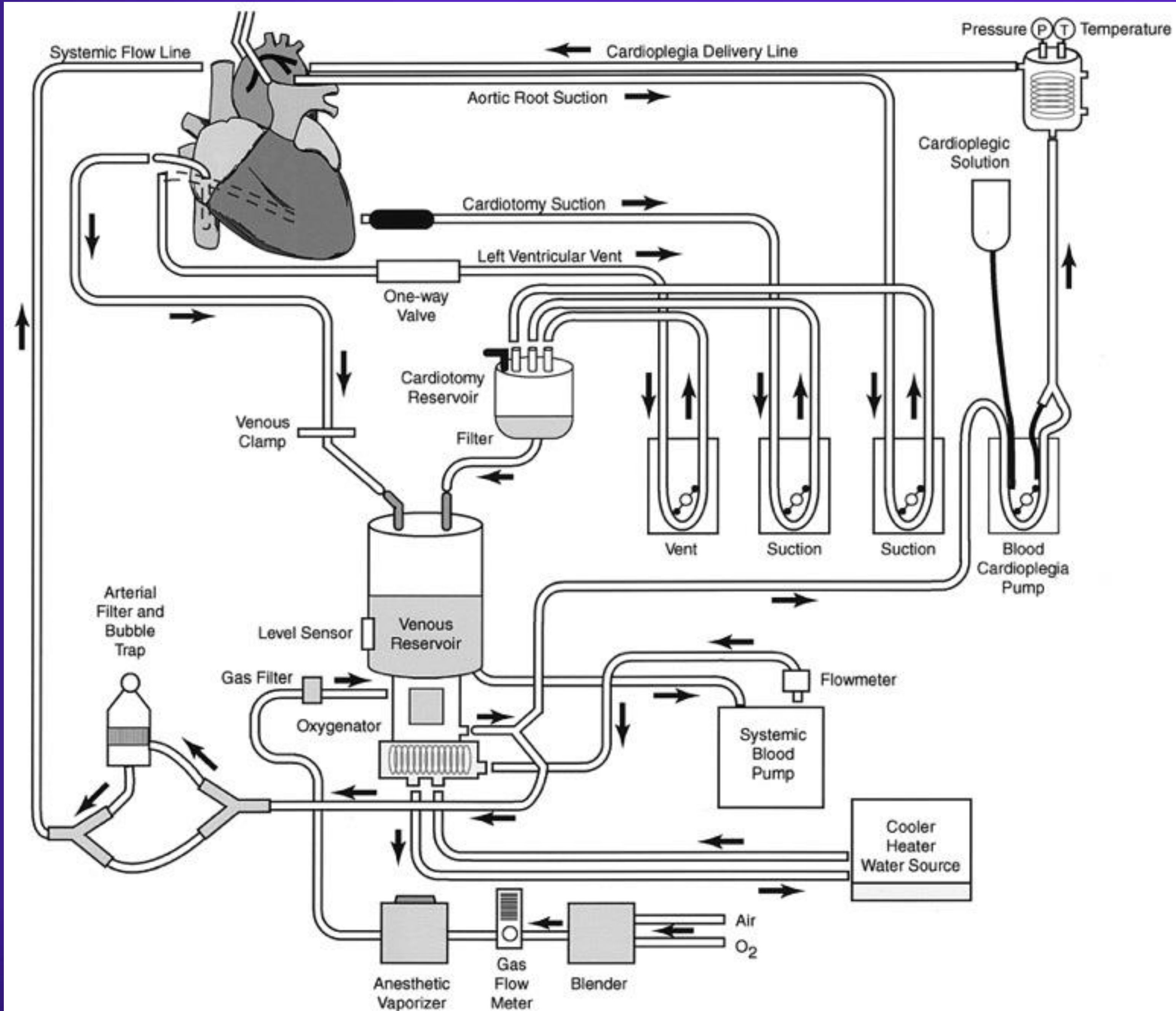
Illustration of controlled cross-circulation as described by Walton Lillehei in 1954.

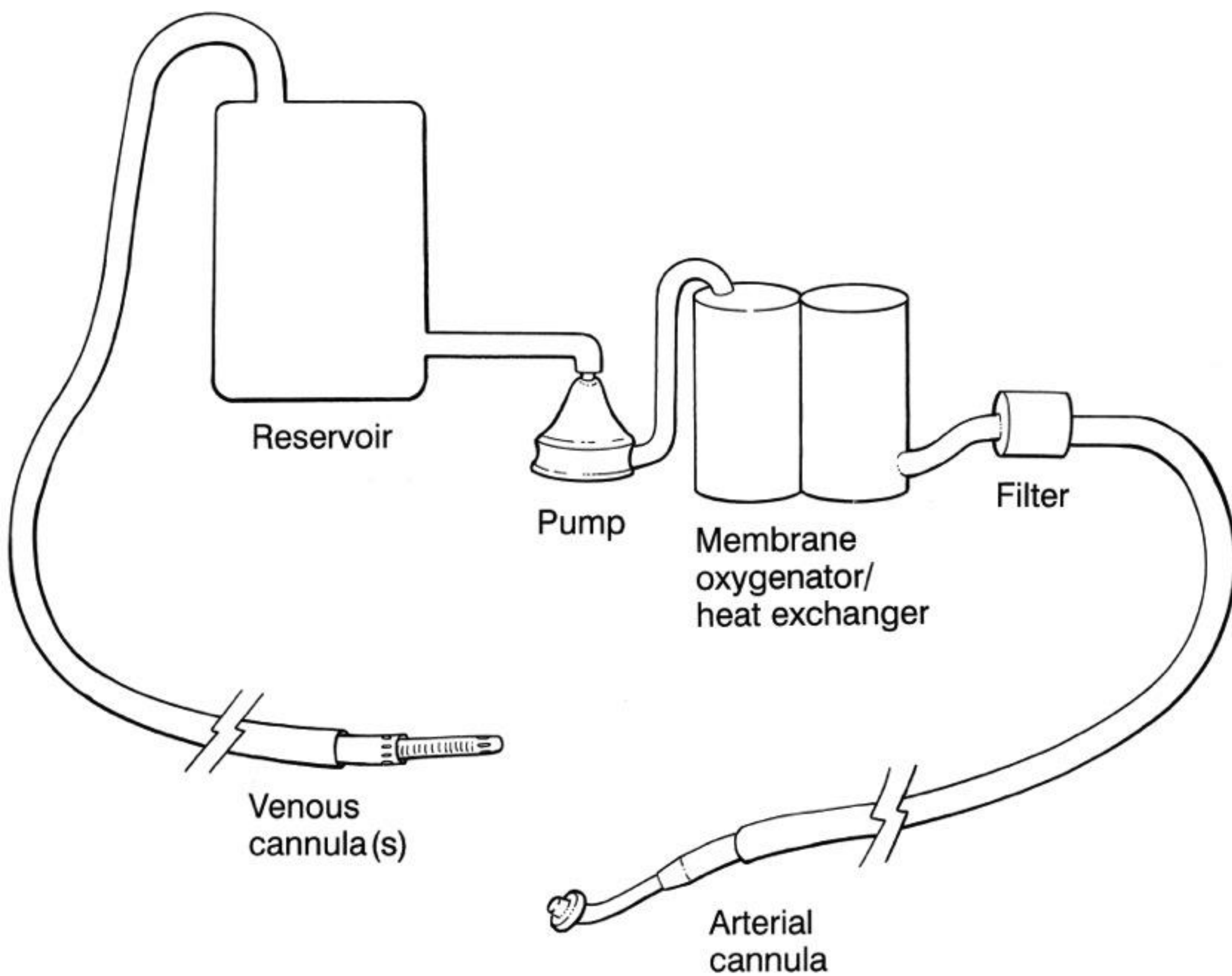
Cardiopulmonary bypass



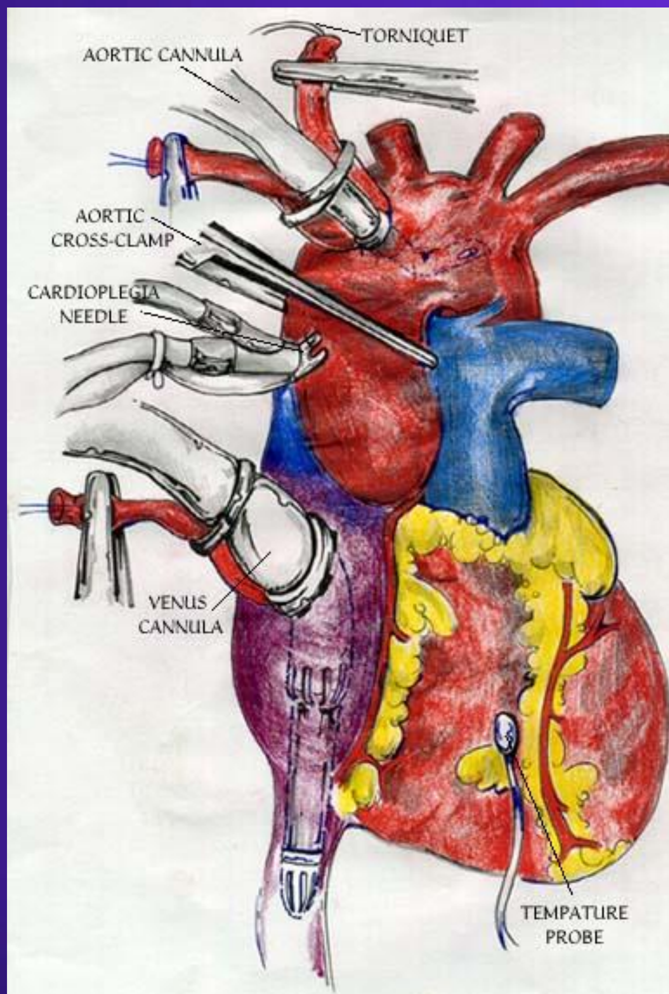


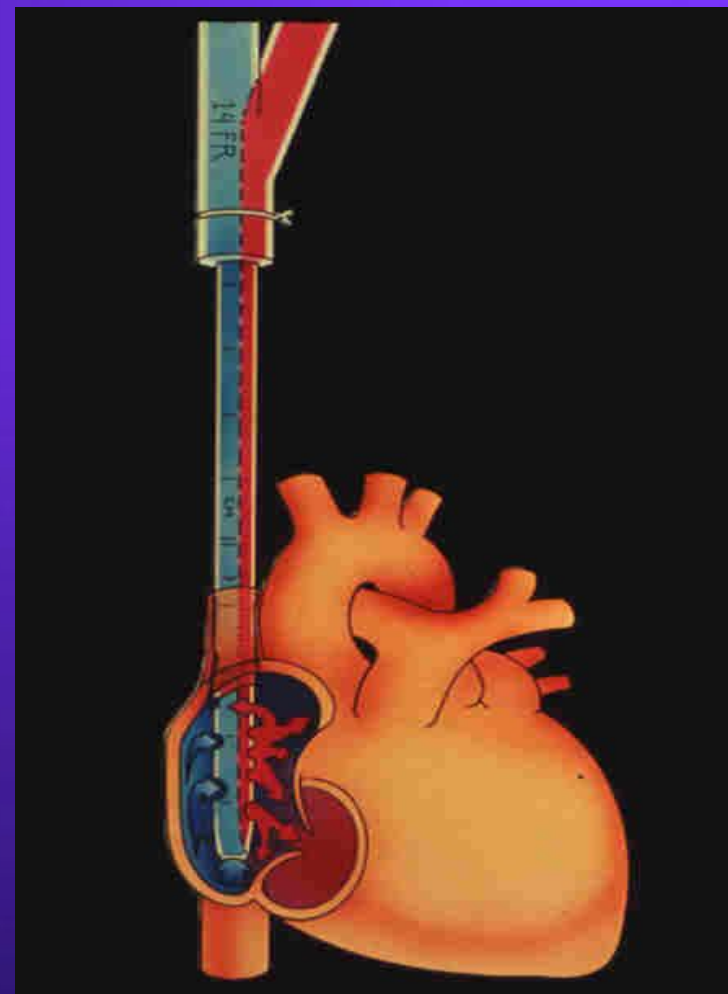



Pressure
P
T
Temperature
Systemic Flow Line
Cardioplegia Delivery Line
Aortic Root Suction
Cardioplegic Solution
Cardiotomy Suction
Left Ventricular Vent
One-way Valve
Cardiotomy Reservoir
Venous Clamp
Filter
Vent
Suction
Suction
Blood Cardioplegia Pump
Arterial Filter and Bubble Trap
Level Sensor
Venous Reservoir
Gas Filter
Flowmeter
Oxygenator
Systemic Blood Pump
Cooler Heater Water Source
Air
O_2
Anesthetic Vaporizer
Gas Flow Meter
Blender


Reservoir
Pump
Membrane
oxygenator/
heat exchanger
Filter
Venous
cannula (s)
Arterial
cannula

CPB and ECMO


TORNIQUET
AORTIC CANNULA
AORTIC
CROSS-CLAMP
CARDIOPLEGIA
NEEDLE
VENUS
CANNULA
TEMPATURE
PROBE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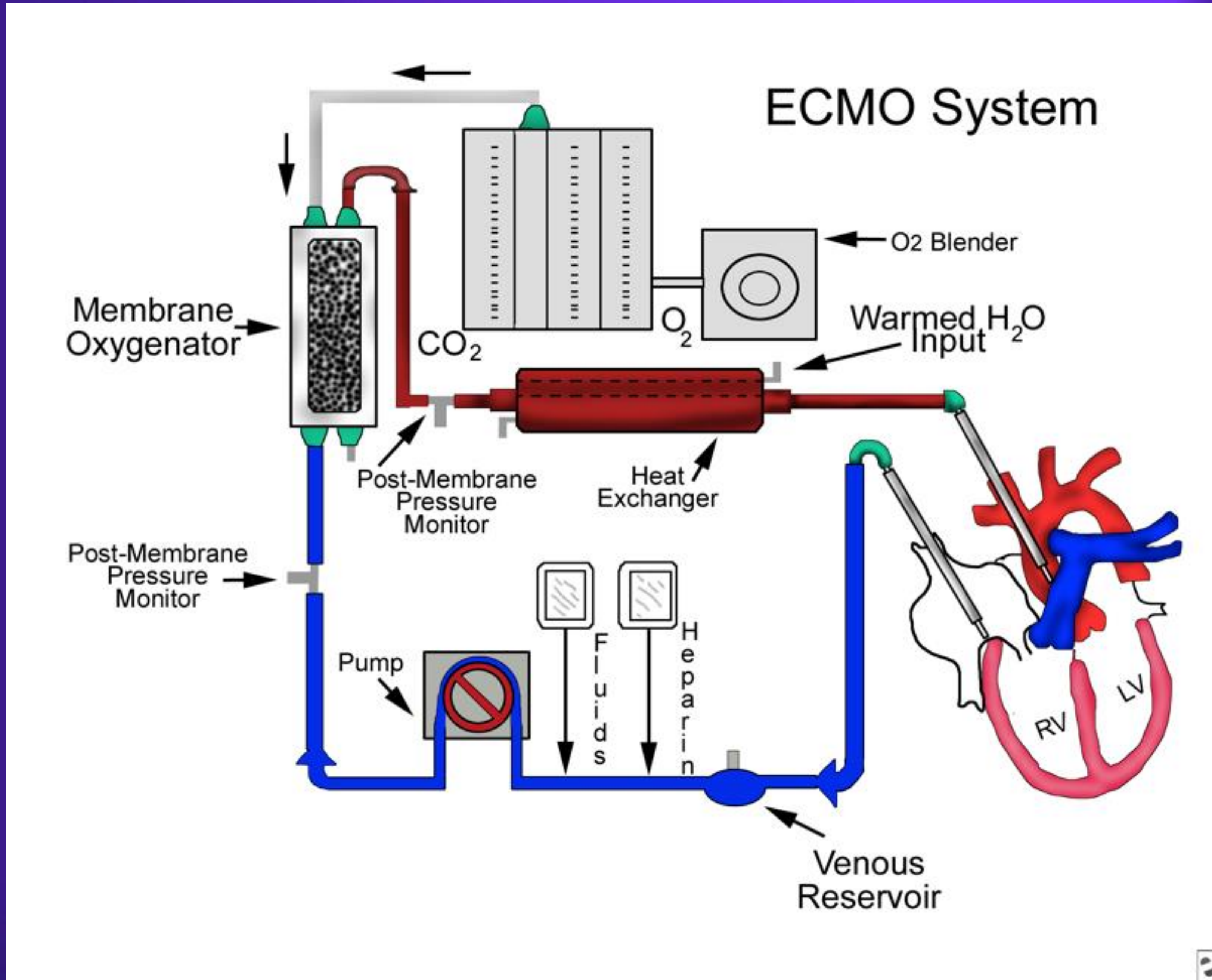

ECMO System
O2 Blender
Membrane Oxygenator
CO_2
O_2
Warmed H_2O Input
Post-Membrane Pressure Monitor
Heat Exchanger
Post-Membrane Pressure Monitor
Pump
Fluids
Heparin
RV
LV
Venous Reservoir

ECMO

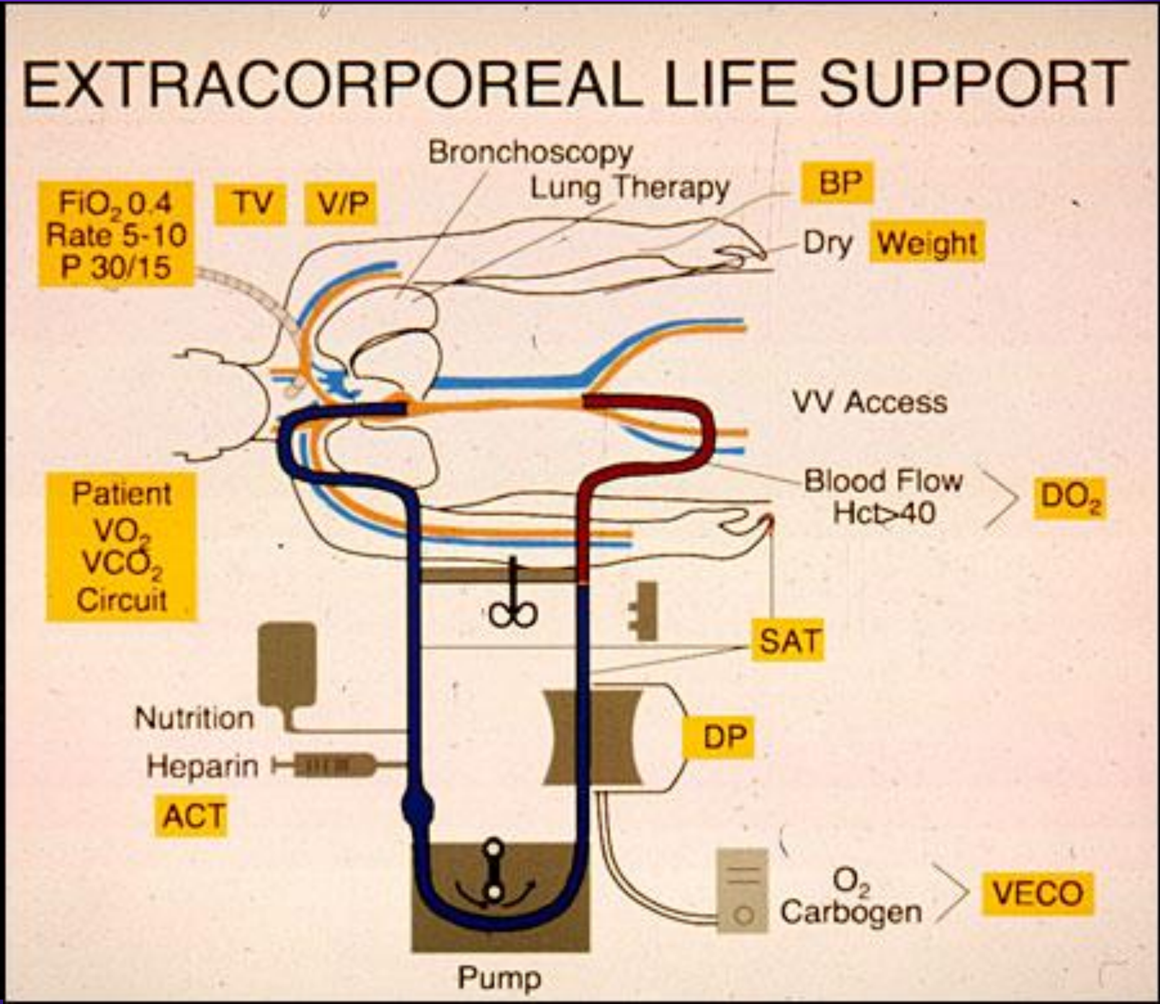
CPB	ECMO
1. Membrane oxygenator	1. Silicone membrane
2. Longer tubing system	2. Smaller tubing system
3. Ordinary membrane oxygenator up to only 8 hr	3. Longer function oxygenator up to 5-7 days
4. Hard shell reservoir	4. Small soft bladder reservoir
5. High-dose heparinisation	5. Lower and titratable heparinisation
6. Higher priming	6. Smaller priming volume

First successful ECLS in an adult

ECMO for "Hope" Esperanza

- **Robert H. Bartlett, M.D.**
- *"In 1975 we were asked to see a newborn infant with meconium aspiration and persistent fetal circulation in the neonatal ICU. We attached this little girl to our laboratory heart-lung machine. The nurses named this child **Esperanza**, "hope" in Spanish. After three days on extracorporeal support Esperanza recovered, leading to continued application of this technology to other newborn infants with respiratory and cardiac failure from a variety of problems."*

ECMO for “Hope” Esperanza



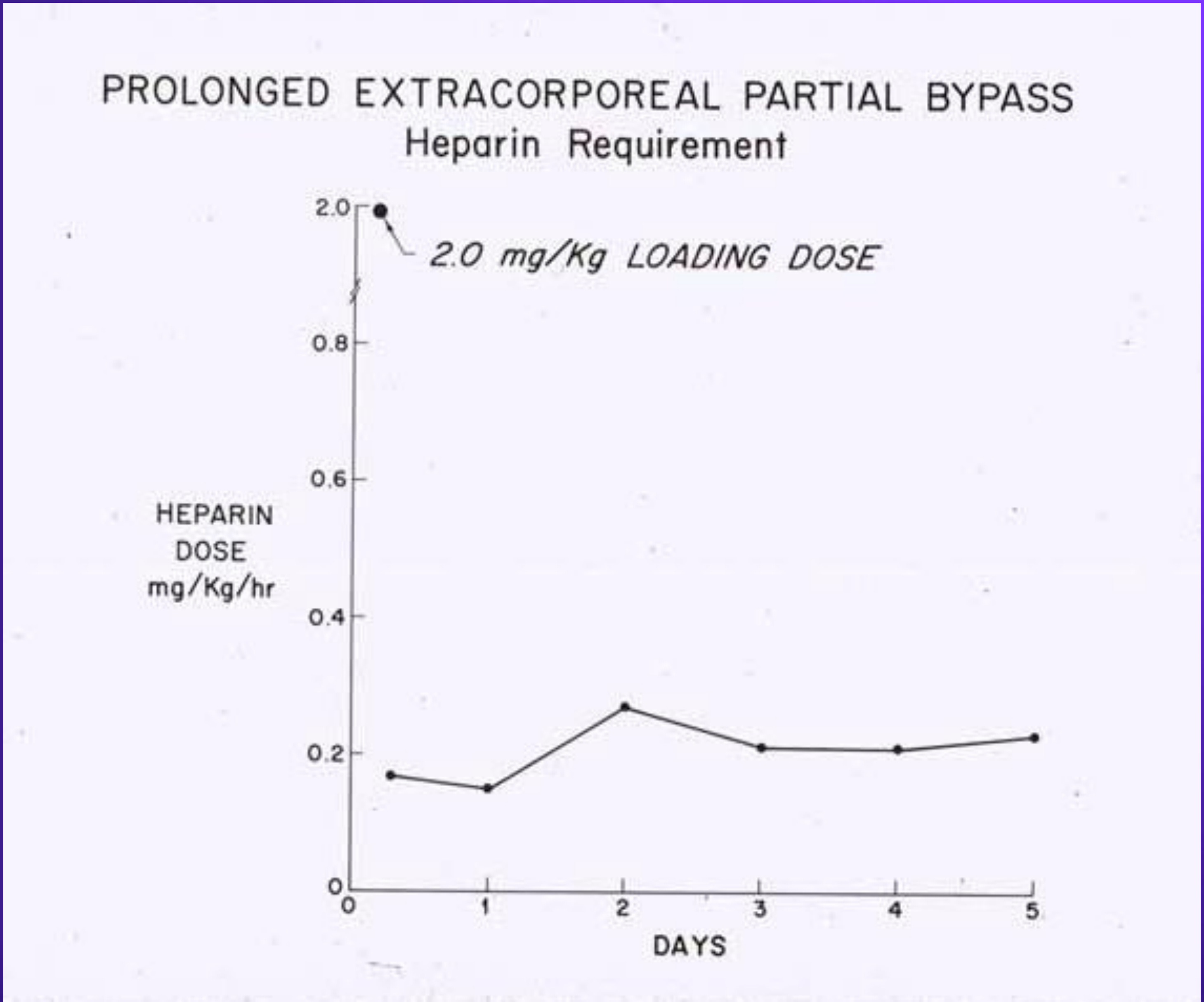
ECMO

- Dr Bartlett’s idea
- *„We spoke of one week ECMO as if it was like flying to the moon“*

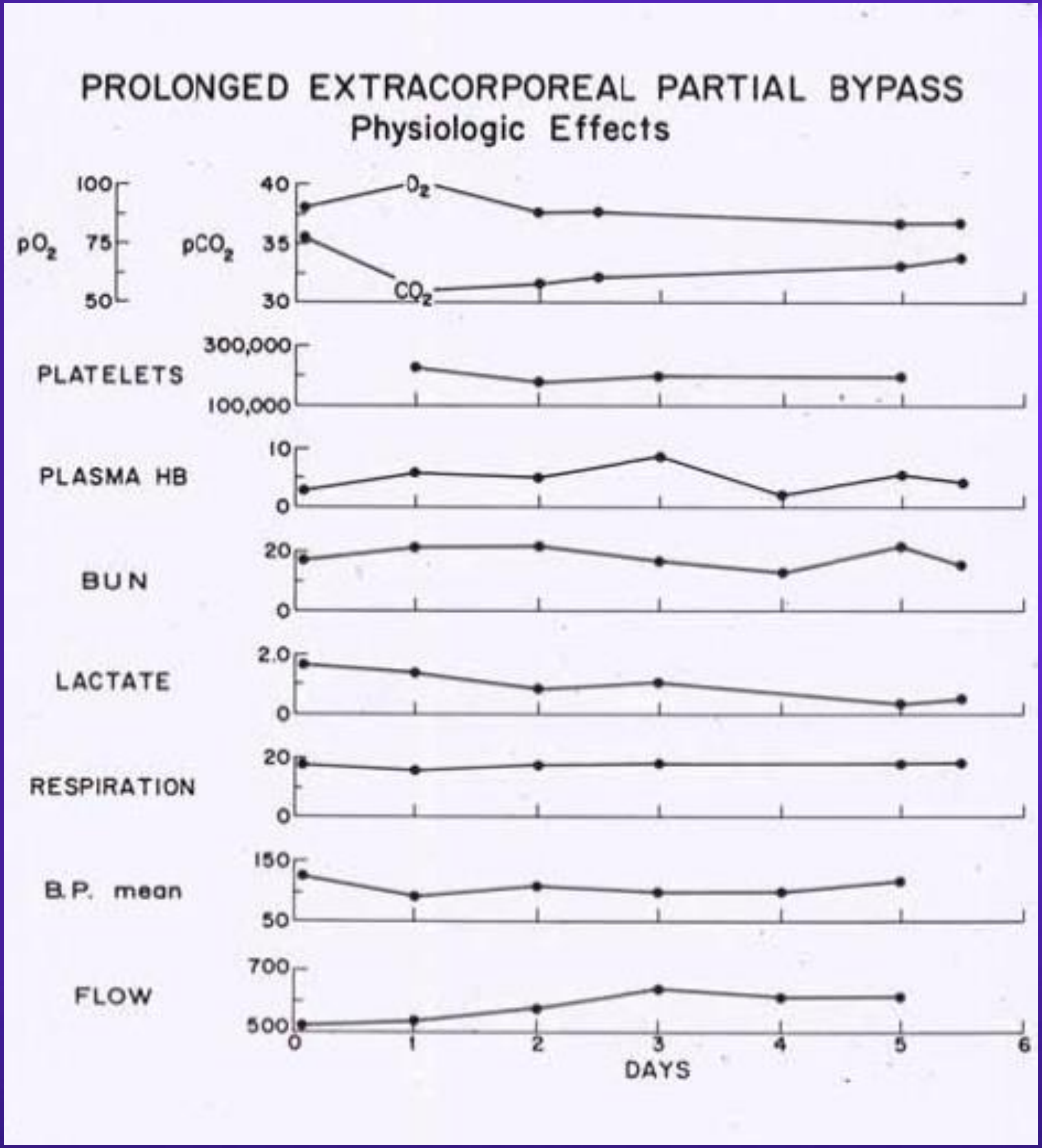
☐ Developed the concept of titrating heparin –which substantionally reduced bleeding complications.

☐ Refined circuit design with exclusion of stagnant flow areas.

Phil Drinker, PhD



Drinker and Bartlett, 1968



Drinker and Bartlett, 1968

Esperanza at 1 day old

Esperanza at 34 years old

THE CURRENT ERA

Current advances

- Expanded indications
- Rationale use
- Advancing perfusion technology

Category I: Cardiac support

- In case of low cardiac output or cardiac dysfunction of any cause and unresponsive to inotropic drugs and intra-aortic balloon pump.
- Post-cardiac surgery
- Post acute myocardial infarction with cardiogenic shock
- Acute fulminating myocarditis
- End-stage CHF
- Post-CPR (extracorporeal CPR, ECPR)

Adult group

Indication for ECMO in adult cardiac failure is cardiogenic shock:

- Inadequate tissue perfusion manifested as hypotension and low cardiac output despite adequate intravascular volume.
- Shock persists despite volume administration, inotropes and vasoconstrictors, and intraaortic balloon counterpulsation if appropriate.
- Typical causes: Acute myocardial infarction, Myocarditis, Peripartum Cardiomyopathy, Decompensated chronic heart failure, Post cardiotomy shock.
- Septic Shock is an indication in some centres.

Guidelines on relative survival without ECMO:

Options for temporary circulatory support

- Surgical temporary VAD: Abiomed, Levitronix
- Percutaneous VAD:TandemHeart, Impella

- ECMO: Advantages: Biventricular support, bedside immediate application, oxygenation, Biventricular failure, Refractory malignant arrhythmias, Heart failure with severe pulmonary failure
- ECMO is a bridge to…
  - Recovery: Acute MI after revascularisation, Myocarditis, Postcardiotomy
  - Transplant: Unrevascularisable acute MI, Chronic heart failure
  - Implantable circulatory support: VAD, TAH

ECPR group

Indications

- AHA guidelines for CPR recommends consideration of ECMO to aid cardiopulmonary resuscitation in patients who have an easily reversible event, have had excellent CPR.

Contraindications:

- All contraindications to ECMO use (such as Gestational age < 34 weeks) should apply to ECPR patients.

Futility: Unsuccessful CPR (no return of spontaneous circulation) for 5-30 minutes.

ECPR may be indicated on prolonged CPR if good perfusion and metabolic support is documented.

Benefit of ECPR over conventional CPR in in-hospital witness arrest

Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis

Yih-Sharng Chen*, Jou-Wei Lin*, Hsi-Yu Yu, Wen-Je Ko, Jih-Shuin Jerng, Wei-Tien Chang, Wen-Jone Chen, Shu-Chien Huang, Nai-Hsin Chi, Chih-Hsien Wang, Li-Chin Chen, Pi-Ru Tsai, Sheoi-Shen Wang, Juey-Jen Hwang, Fang-Yue Lin

Summary

Background Extracorporeal life-support as an adjunct to cardiac resuscitation has shown encouraging outcomes in patients with cardiac arrest. However, there is little evidence about the benefit of the procedure compared conventional cardiopulmonary resuscitation (CPR), especially when continued for more than 10 min. W assess whether extracorporeal CPR was better than conventional CPR for patients with in-hospit cardiac origin.

Cardiology in the Young (2011), **21**(Suppl. 2), 109–117
doi:10.1017/S1047951111001685

Original Article

Extracorporeal cardio ... tion for post-operative cardiac ... ons, techniques, controversies, and early ... what is known (and unknown)

Paul J. Chai,[1] Jeffrey P. Jacobs,[1] Heidi J. Dalton,[2] John M. Costello,[3] David S. Cooper,[1] Roxanne Kirsch,[4] Tami Rosenthal,[4] Joseph N. Graziano,[2] James A. Quintessenza[1]

[1]*The Congenital Heart Institute of Florida, All Children's Hospital, Saint Petersburg, Florida;* [2]*Division Chief and Professor of Child Health, Phoenix Children's Hospital and University of Arizona College of Medicine, Phoenix;* [3]*Children's Memorial Hospital, Feinberg School of Medicine, Northwestern University, Chicago, Illinois;* [4]*Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, United States of America*

Extracorporeal cardiopulmonary resuscitation in patients with inhospital cardiac arrest: A comparison with conventional cardiopulmonary resuscitation*

Tae Gun Shin, MD; Jin-Ho Choi, MD, PhD; ... Min Seob Sim, MD; Hyoung Gon Song, MD, PhD; ... Song, MD, PhD; Joo-Yong Hahn, MD, PhD; ... Gwon, MD, PhD; Eun-Seok Jeon, MD, ... PhD; Young Tak Lee, MD, PhD

Objective ... with in ... 406 adult patients ... receiving cardiopulmonary ... January 2003 to June 2009 (85 in ... cardiopulmonary resuscitation group and 321 in ... pulmonary resuscitation group).

Measurements and Main Results: The primary end point was a ... discharge with minimal neurologic impairment. Propensity score matching was used to balance the baseline characteristics and cardiopulmonary resuscitation variables that could potentially affect prognosis. In the matched population (n = 120), the survival discharge rate with minimal neurologic impairment in the extracorporeal cardiopulmonary resuscitation group was sig- ... than that in the conventional cardiopulmonary ... group (odds ratio of mortality or significant neuro- ... deficit, 0.17; 95% confidence interval, 0.04–0.68; p = .012). In addition, there was a significant difference in the 6-month survival rates with minimal neurologic impairment (hazard ratio, 0.48; 95% confidence interval, 0.29–0.77; p = .003; p <.001 by stratified log-rank test). In the subgroup based on cardiac origin, extracorporeal cardiopulmonary resuscitation also showed benefits for survival discharge (odds ratio, 0.19; 95% confidence interval, 0.04–0.82; p = .026) and 6-month survival with minimal neurologic impairment (hazard ratio, 0.56; 95% confidence interval, 0.33–0.97; p = .038; p = .013 by stratified log-rank test).

Conclusions: Extracorporeal cardiopulmonary resuscitation showed a survival benefit over conventional cardiopulmonary resuscitation in patients who received cardiopulmonary resuscitation for >10 mins after witnessed inhospital arrest, especially in cases with cardiac origins. (Crit Care Med 2011; 39:1–7)

KEY WORDS: cardiopulmonary resuscitation; extracorporeal membrane oxygenation; cardiopulmonary bypass; extracorporeal circulation; cardiopulmonary arrest; advanced cardiac life support

Resuscitation 83 (2012) 1331–1337

Contents lists available at SciVerse ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

A 5-year experience with cardiopulmonary resuscitation using extracorporeal life support in non-postcardiotomy patients with cardiac arrest☆

Assad Haneya[a,*], Alois Philipp[a], Claudius Diez[a], Simon Schopka[a], Thomas Bein[b], Markus Zimmermann[b], Matthias Lubnow[c], Andreas Luchner[c], Ayman Agha[d], Michael Hilker[a], Stephan Hirt[a], Christof Schmid[a], Thomas Müller[c]

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Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis

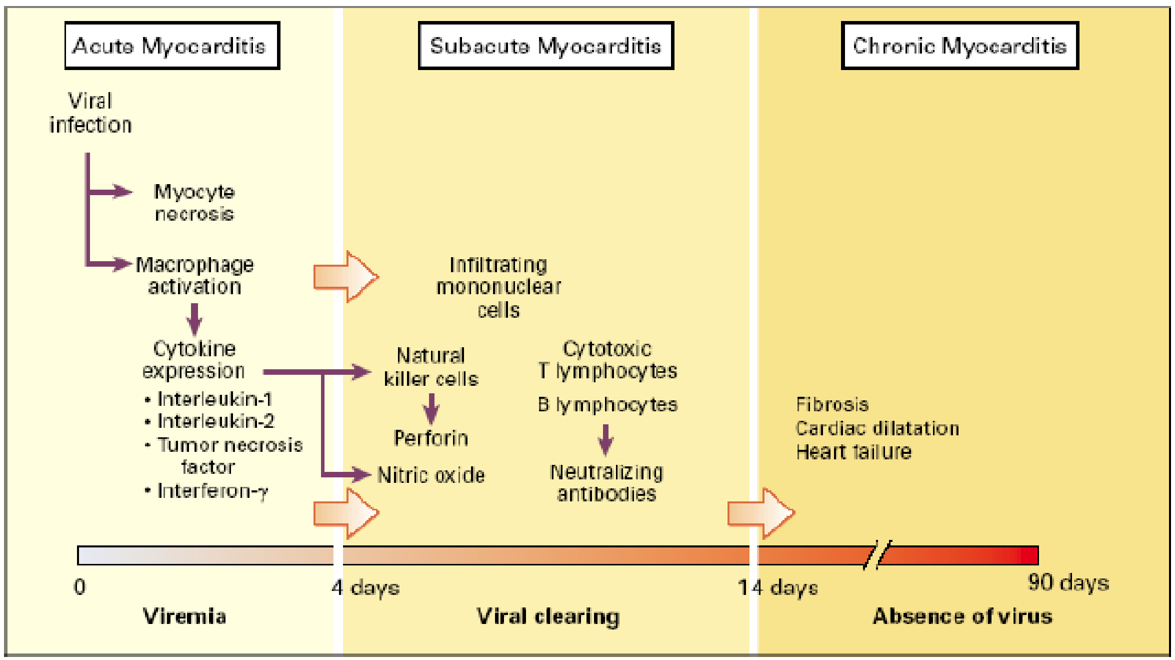
- Of the 975 patients with in-hospital cardiac arrest events who underwent CPR for longer than 10 min, 113 were enrolled in the conventional CPR group and 59 were enrolled in the extracorporeal CPR group. Unmatched patients who underwent extracorporeal CPR had a higher survival rate to discharge (log-rank p<0·0001) and a better 1-year survival than those who received conventional CPR (log rank p=0·007). Between the propensity-score matched groups, there was still a significant difference in survival to discharge (hazard ratio [HR] 0·51, 95% CI 0·35–0·74, p<0·0001), 30-day survival (HR 0·47, 95% CI 0·28–0·77, p=0·003), and 1-year survival (HR 0·53, 95% CI 0·33–0·83, p=0·006) favouring extracorporeal CPR over conventional CPR.

The Lancet, 372(9638), p554–561

ECMO and acute myocarditis

Pathogenesis

Direct myocyte injury



Immunological activation

Autoimmune mediated

(Magnani JW, Dec GW. "Myocarditis: current trends in diagnosis and treatment." *Circulation*. 2006 Feb 14;113(6):876-90.

MCS Devices to support Myocarditis

Acute Myocarditis

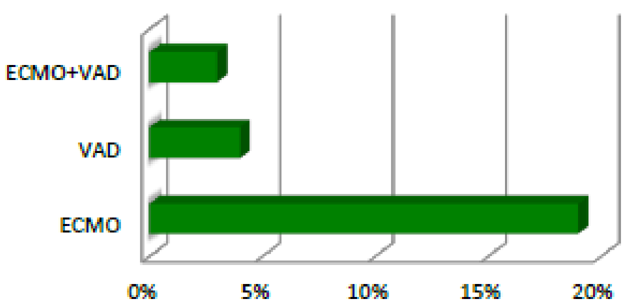
Fulminant Myocarditis
Lung Injury
CPR

ECMO

Heart Failure / DCM
Slow Deterioration
Increasing Support

Short Term VAD
Durable VAD

Type of MCS in Myocarditis



Limited data:
No recovery of ejection by 72 hours
Inability to wean by day ~ 7 of support

Ghelani S. Circ Cardiovascul Qual Outcomes 2012

Rationale behind ECMO support for myocarditis

- Timely ECMO deployment
- Early LV decompression
  - Promotes Myocardial Recovery
  - Decreased lung Injury due to decreased LAP
- Timely transition to VAD & Heart Transplantation evaluation

Category II

Respiratory support

- Adult respiratory failure
- Neonatal respiratory failure
- Paediatric respiratory failure

Category II: adult

Indications

- In hypoxic respiratory failure due to any cause (primary or secondary) ECLS should be considered when the risk of mortality is 50% or greater, and is indicated when the risk of mortality is 80% or greater.
  - 50% mortality risk is associated with a PaO_2 /FiO_2 < 150 on FiO_2 > 90% and/or Murray score 2-3.
  - 80% mortality risk is associated with a PaO_2 /FiO_2 < 100 on FiO_2> 90% and/or Murray score 3-4 despite optimal care for 6 hours or more.
- CO_2 retention on mechanical ventilation despite high Pplat (>30 cm H_2O)
- Severe air leak syndromes
- Need for intubation in a patient on lung transplant list
- Immediate cardiac or respiratory collapse (PE, blocked airway, unresponsive to optimal care)

CESAR: conventional ventilatory support vs extracorporeal membrane oxygenation for severe adult respiratory failure

Giles J Peek*[1], Felicity Clemens[2], Diana Elbourne[2], Richard Firmin[1], Pollyanna Hardy[2,3], Clare Hibbert[5], Hilliary Killer[1], Miranda Mugford[4], Mariamma Thalanany[4], Ravin Tiruvoipati[1], Ann Truesdale[2] and Andrew Wilson[6]

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Paediatric respiratory failure

Indications: consideration for ECMO is best within the first 7 days of mechanical ventilation at high levels of support

Contraindications

- Recent neurosurgical procedures or intracranial bleeding (within 10 days). Grade II or III intracranial haemorrhage is a general contraindication.
- Recent surgery or trauma: increased risk of bleeding. Care to maintain adequate coagulation factors, platelet counts and use of low ACT's (160-180) may be helpful.
- Age and size: No weight limit although obese patients (especially >100kgs) may require special beds, have high risk of decubiti. May also be more difficult to cannulate.
- Patients with severe neurologic compromise, genetic abnormalities (not including Trisomy 21).
- Relative: end-stage hepatic failure, renal failure, primary pulmonary hypertension.

ECMO indications

- Oxygenation index (OI): if > 40 predicts 80 % mortality without ECMO

$$\frac{MPaw.FiO2.100}{PO2(mmHg)}$$

- MPaw

$$\frac{(Paw.Ti)+(PEEP.Te)}{Ti+Te}$$

Neonatal respiratory failure

Contraindications:

- lethal chromosomal disorder (includes trisomy 13, 18 but not 21) or other lethal anomaly
- Irreversible brain damage
- Uncontrolled bleeding
- Grade III or greater intraventricular haemorrhage.

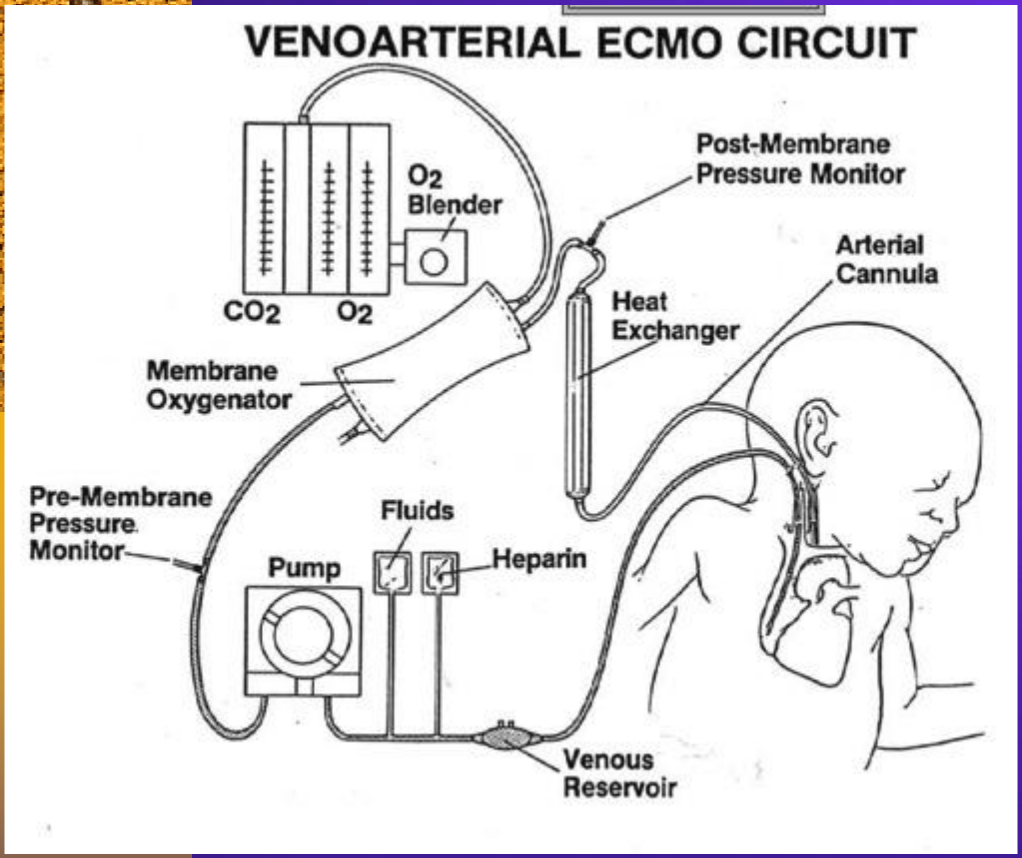
Relative contraindications include

- Irreversible organ damage (unless considered for organ transplant)
- <2 Kg
- <34 weeks GA because of the increased incidence of increased intracranial haemorrhage.
- Mechanical ventilation greater than 10-14 days.
- Patients with disease states with a high probability of a poor prognosis.

Extracorporeal membrane oxygenation (ECMO)

Queen Elizabeth II visited one of ECMO patients at GOSH on its 150th anniversary on 14 February 2002.

Extracorporeal membrane oxygenation (ECMO)



- ***Principle of cardiopulmonary bypass***
- ***VA ECMO***
- ***VV ECMO***

Difference between VA and VV ECMO

Hemodynamics	V-A	V-V
Systemic perfusion	Circuit flow and cardiac output	Cardiac output
Art. BP	Pulse is damped	Pulse is full
CVP	Accurate guide to volume status	Not helpful
PA Pressure	Decrease in proportion to ECC flow	Not affected by flow

Difference between VA and VV

Gas exchange	V-A	V-V
Arterial oxygenation	Sat controlled by ECC flow	80-95% sat common for maximum flow
CO2 removal	Depends of gas sweep and surface area of membrane	Same as VA
Decrease ventilator setting	Rapidly	Slowly

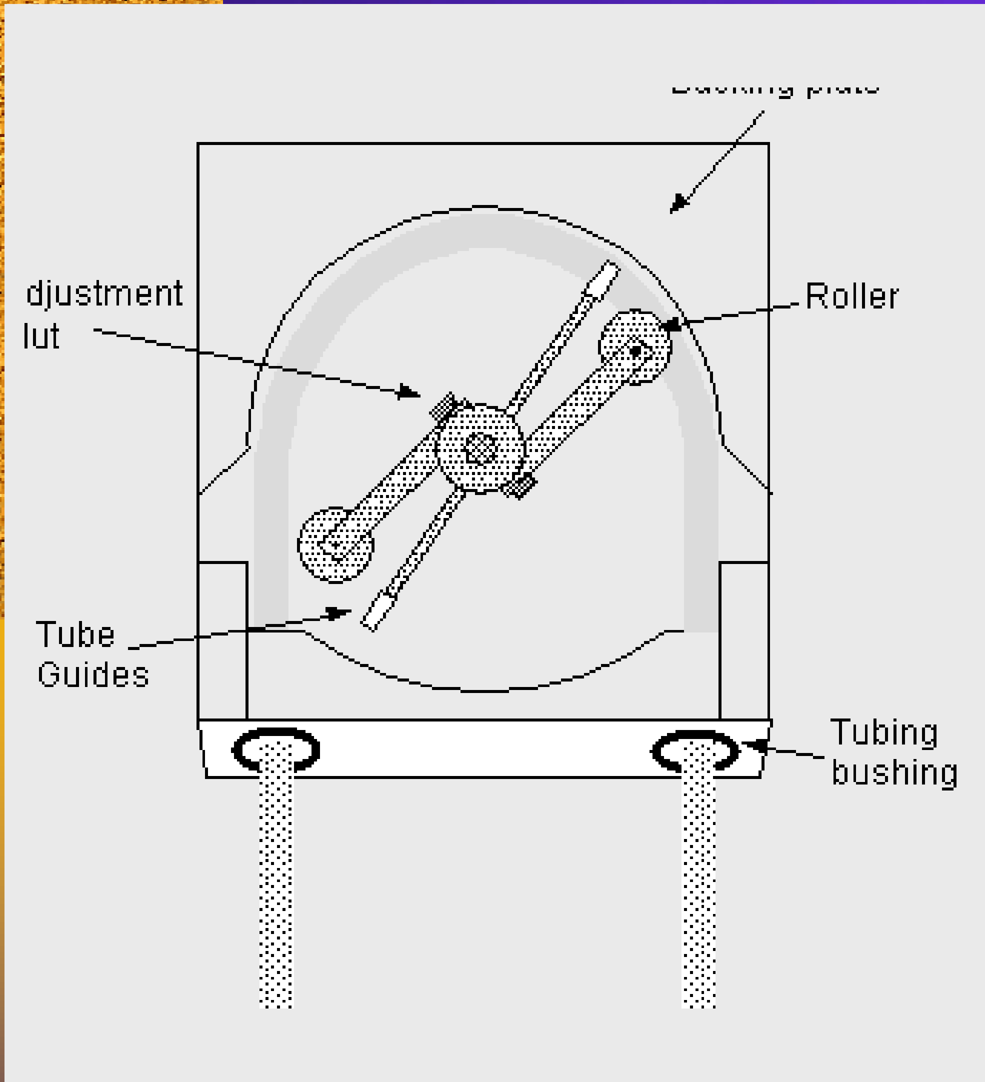
Equipments for ECMO

- Pump: roller or centrifugal
- Membrane oxygenator
- Bladder reservoir
- Tubing
- Cannula
- Air bubble detector
- Heat exchanger
- Additional equipment: haemofiltration

The Heart

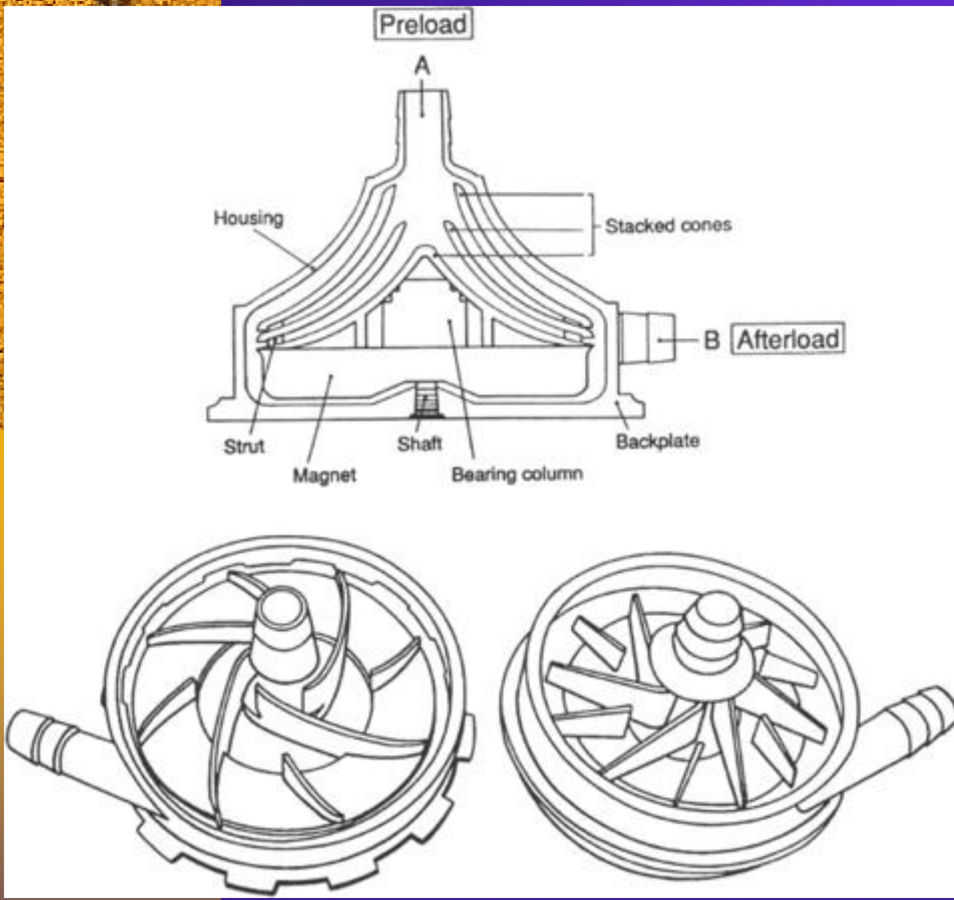
- Roller pump
- Centrifugal pump

- Non pulsatile
- Pulsatile is more physiological


djustment
lut
Roller
Tube
Guides
Tubing
bushing


RPM
LPM
2585
0.84
FRE
LPM Mode
RPM


BIOLINE COATING


Preload
A
Housing
Stacked cones
B
Afterload
Strut
Magnet
Shaft
Bearing column
Backplate

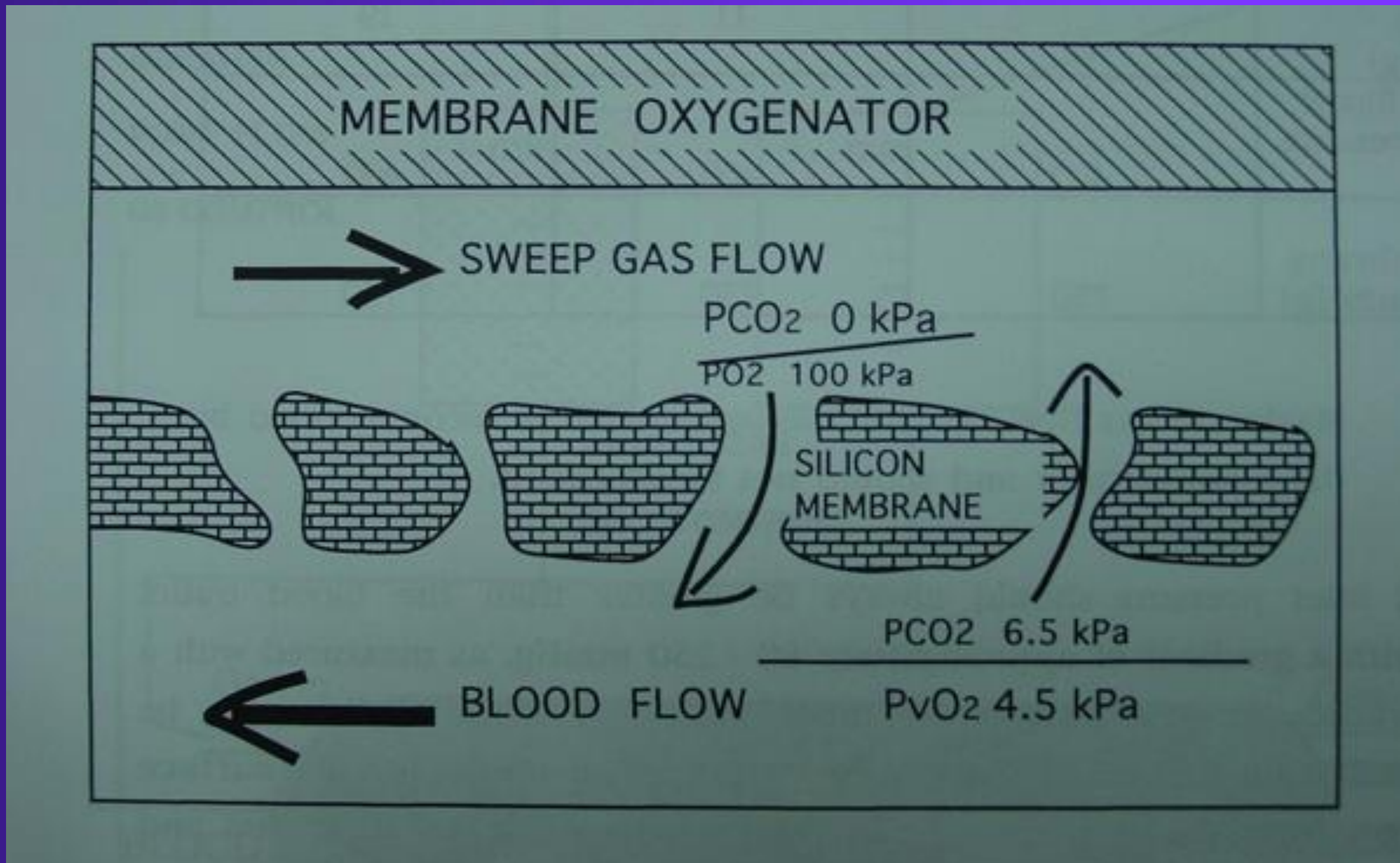
ECMO

- Membrane oxygenator
- Avoid direct contact between oxygen and red blood cell
- Less thrombogenic effect
- Suitable for prolonged use

2 major types

- Hollow fiber
- Silicone membrane

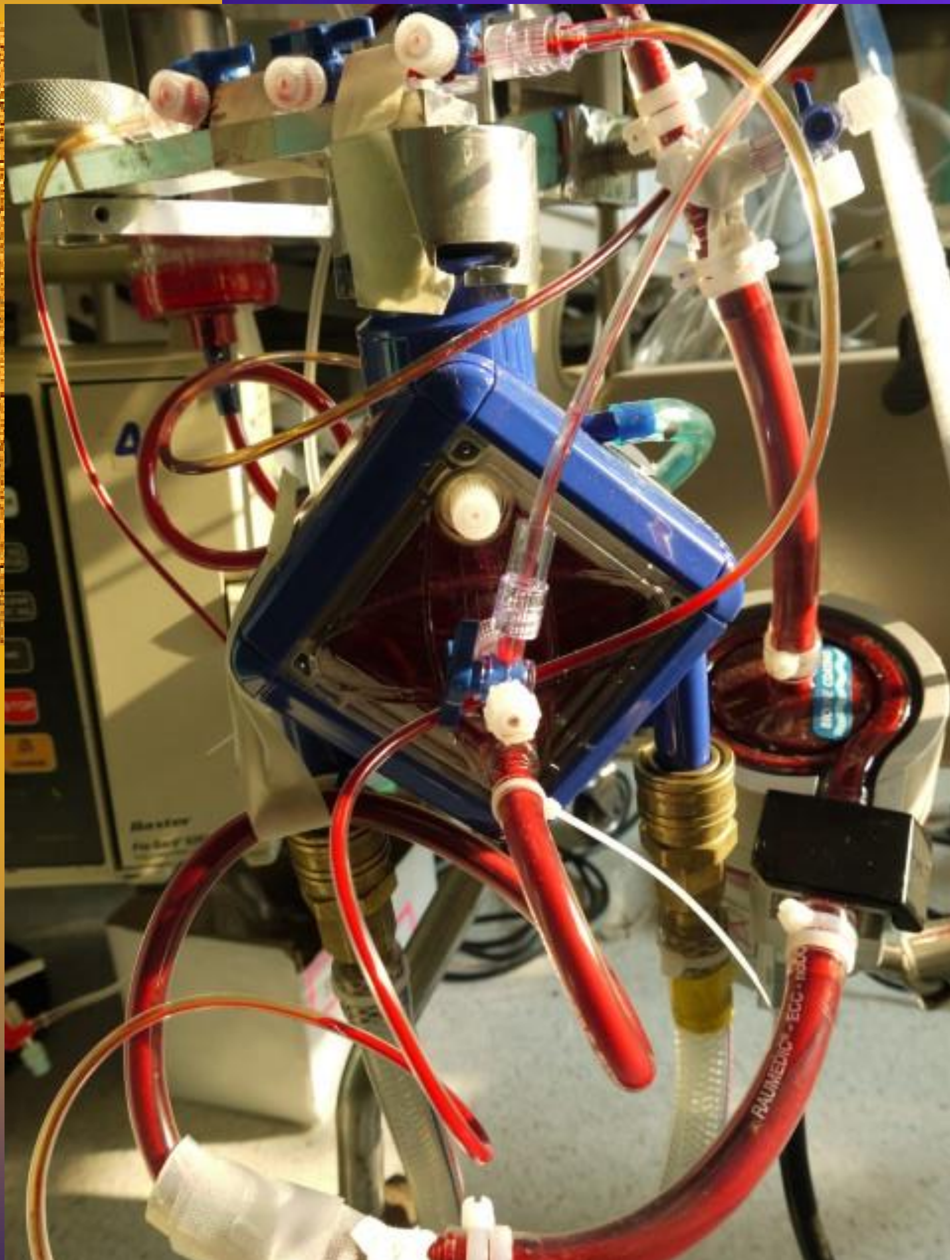
Membrane oxygenator



Silicone membrane

- Silicone membrane
- Rolled silicone sheet
- Plasma leak

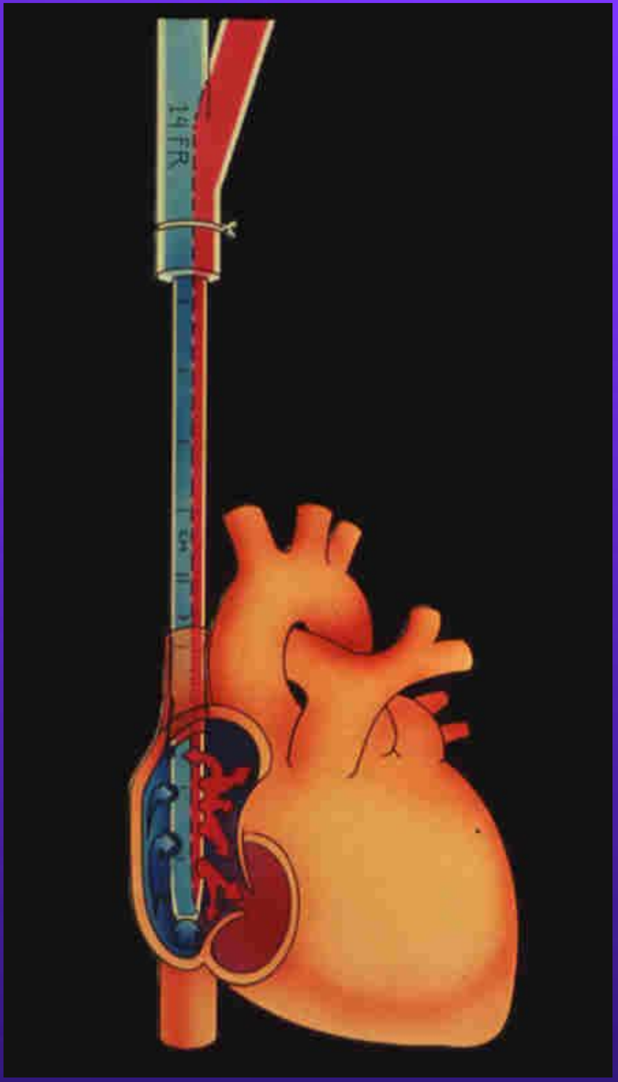
Hollow fiber



Current oxygenator

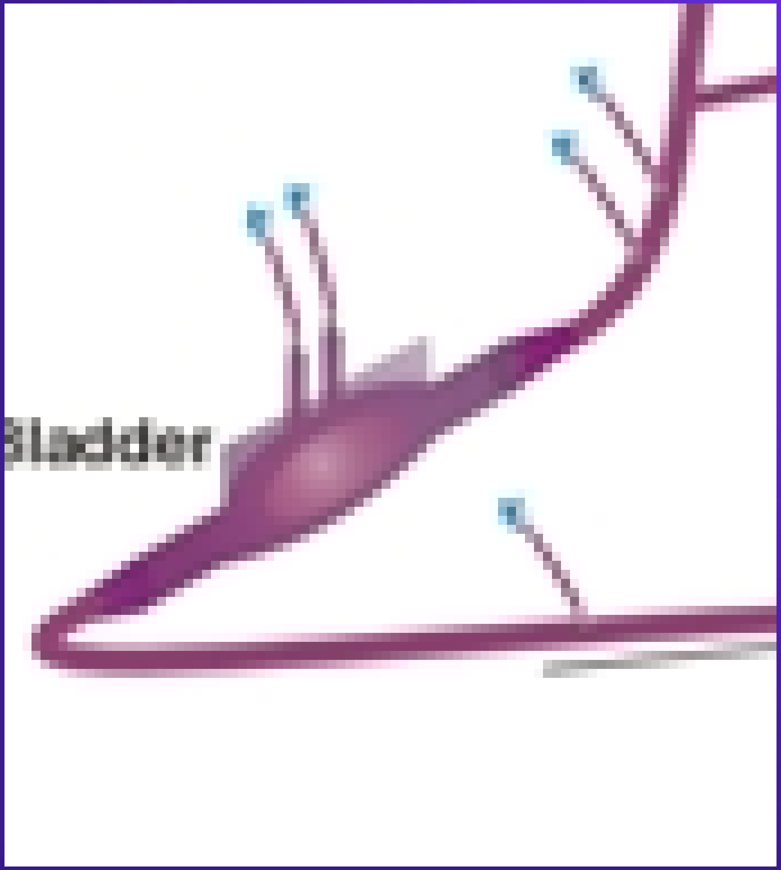
- Hallow fiber
- Polymethylpentene
- Heparin-coated
- Effective in
  - Blood oxygenation
  - CO_2 elimination
  - Low pressure drop
- Last 15-21 days

ECMO cannulae



ECMO cannulae

Bladder reservoir



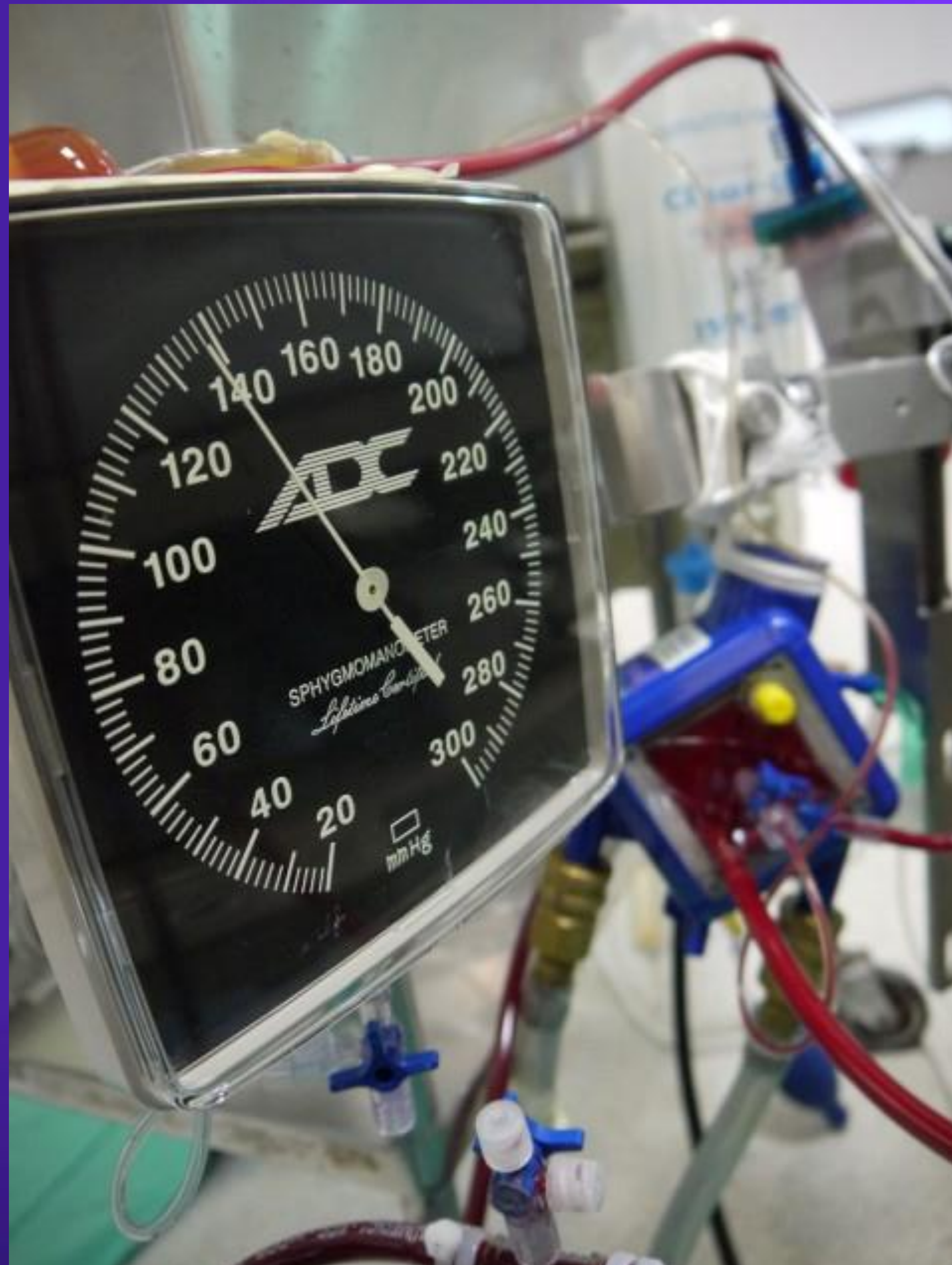
- Soft silicone bag
- Observe amount of blood coming in and out the reservoir

Heat exchanger

Pressure monitor and flow detector

- Pre-membrane and post-membrane pressure monitor
- Flow detector

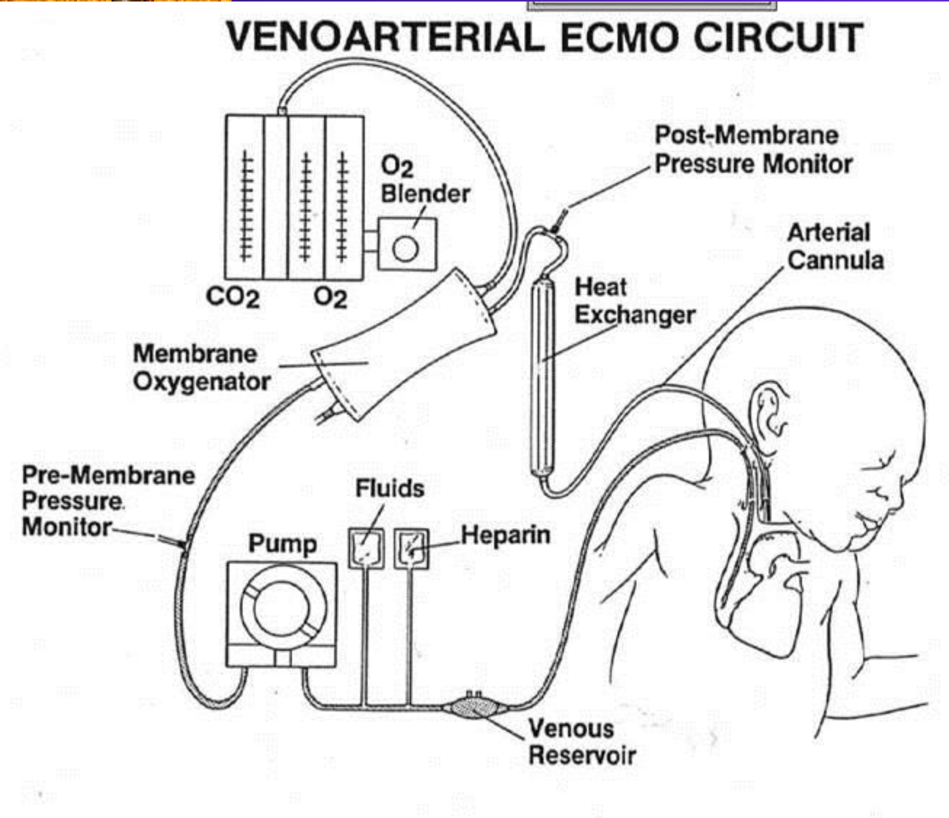

ADC

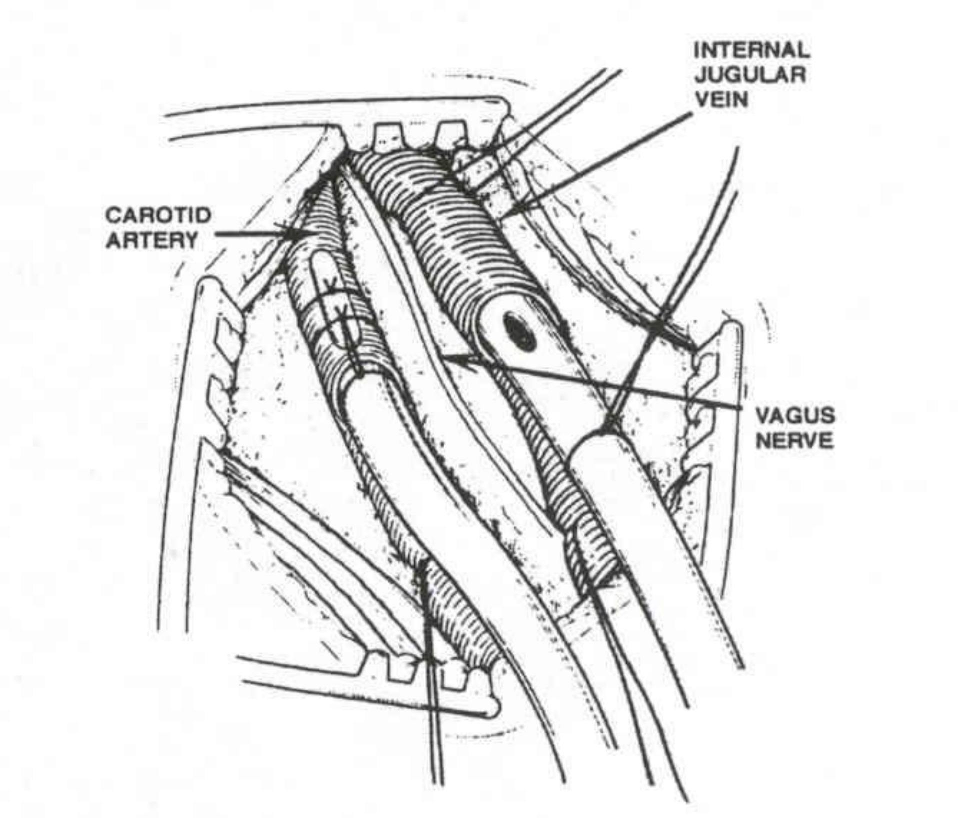

ADC
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
mmHg

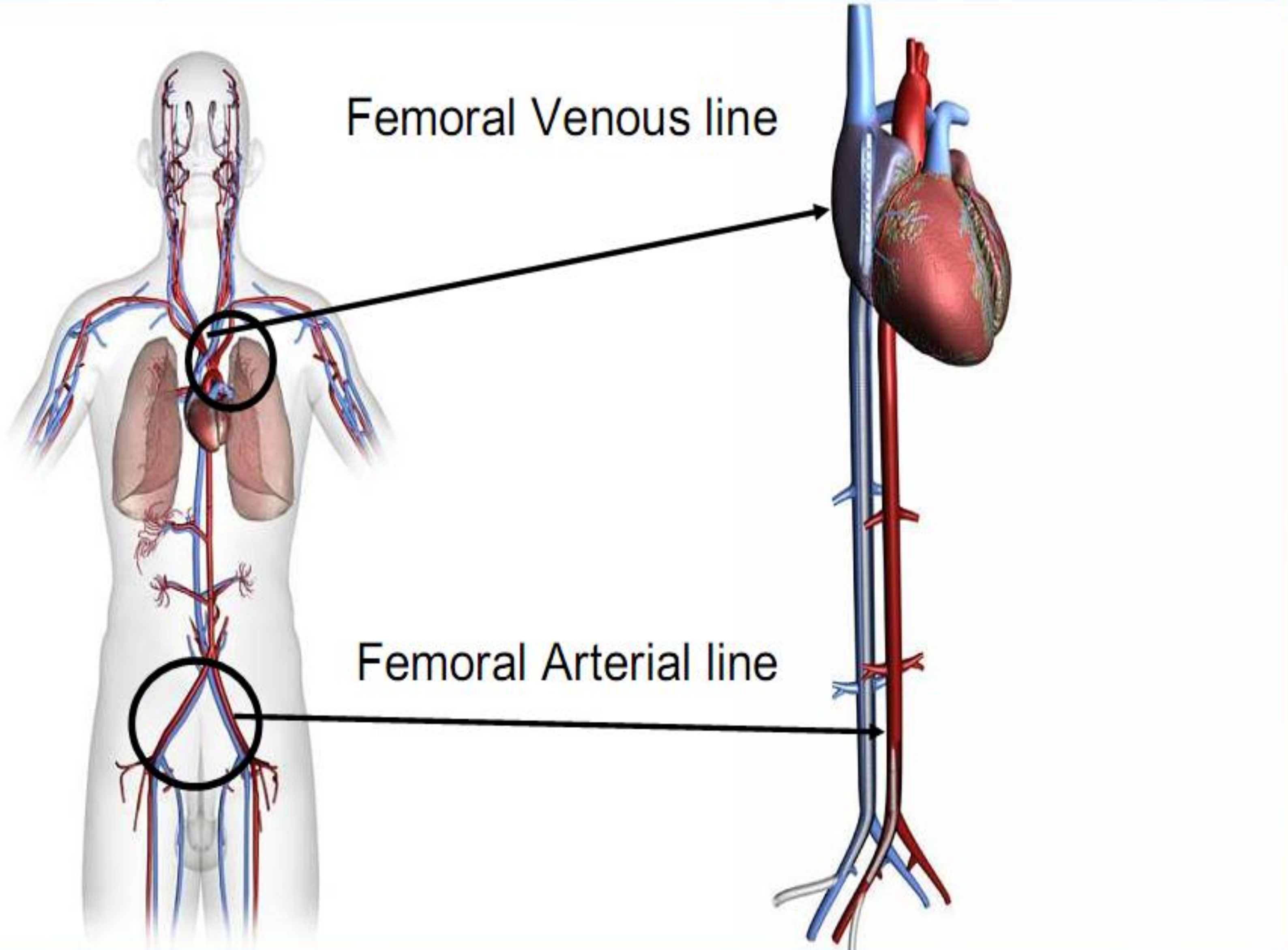
ECMO techniques and cannulation

- Common sites
  1. Venous
     a. right atrium
     b. femoral vein
     c. jugular vein
  2. Arterial
     a. aortic
     b. carotid artery
     c. femoral artery
     d. axillary artery

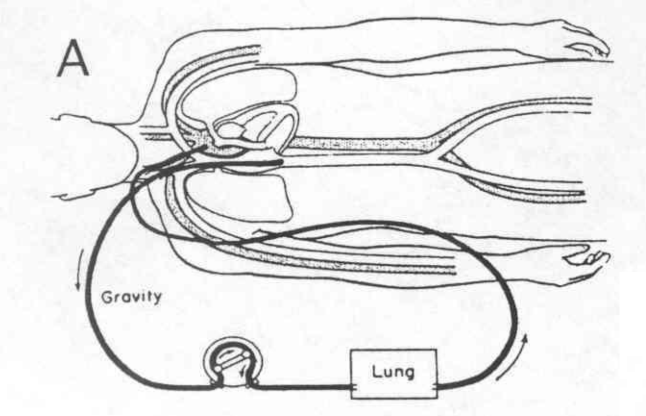
ECMO cannulation

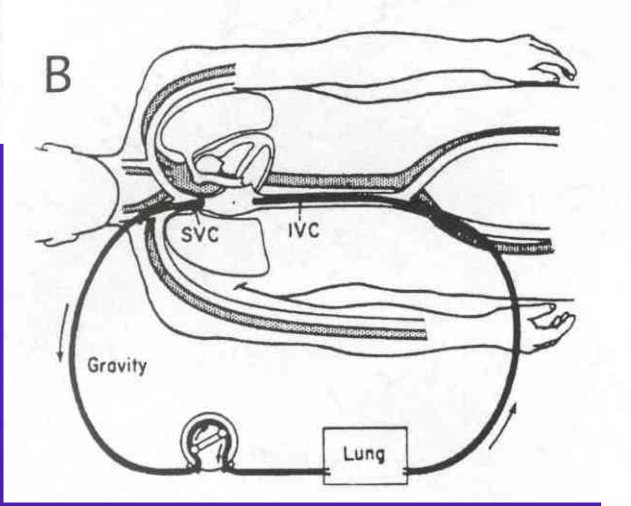


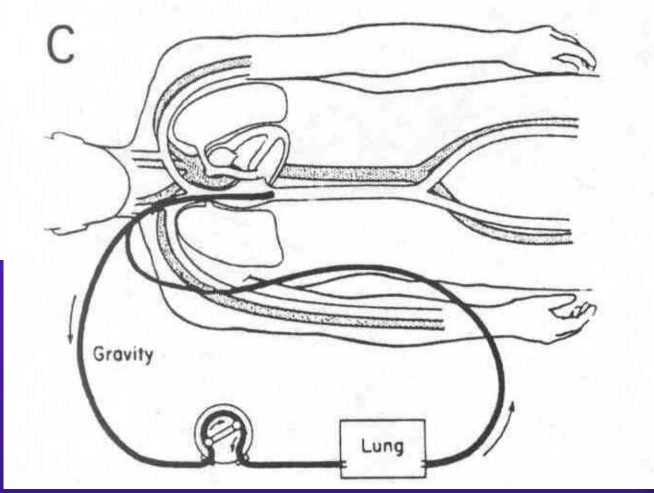


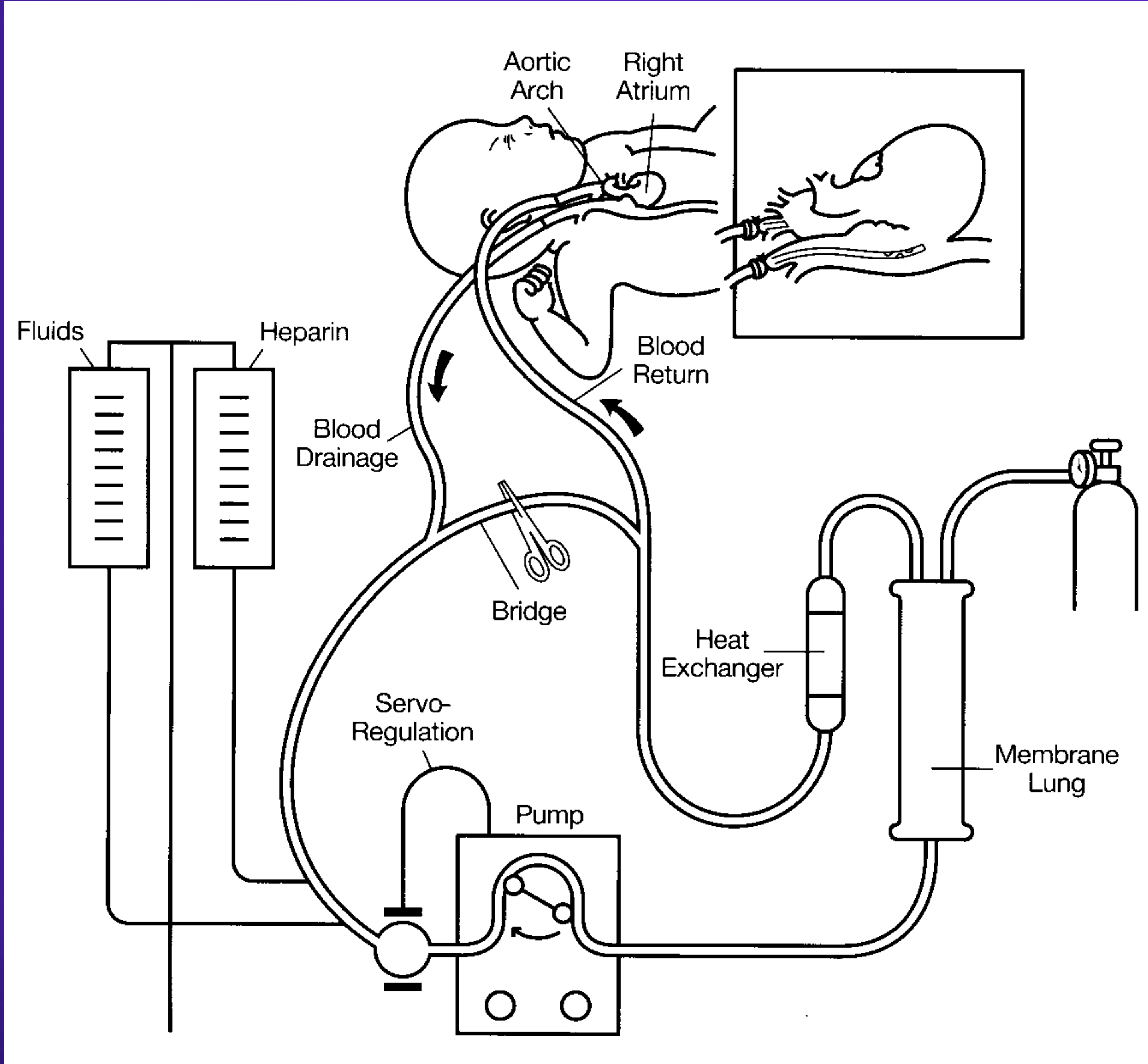

Femoral Venous line
Femoral Arterial line

ECMO circuits



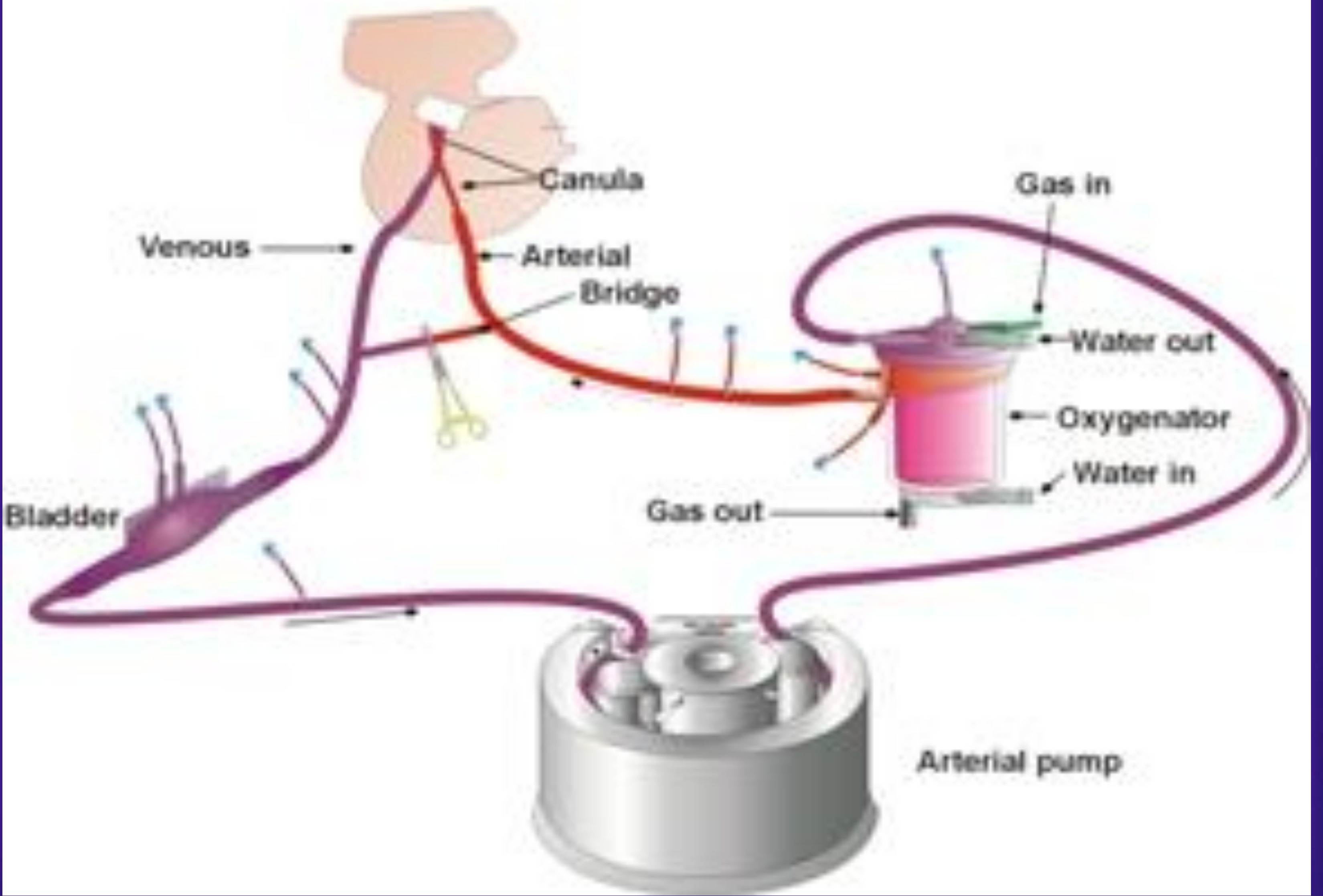


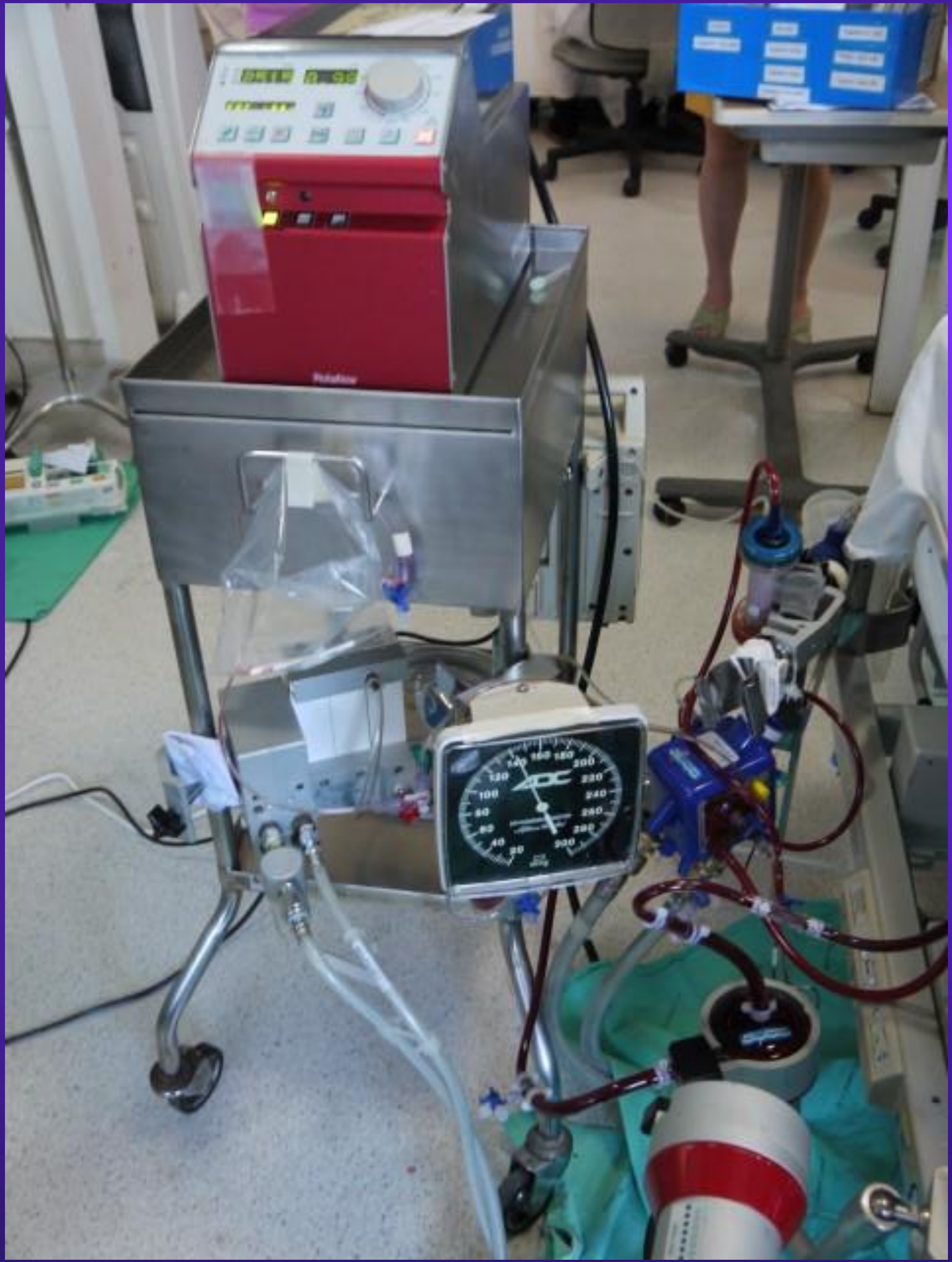




Aortic Arch
Right Atrium
Fluids
Heparin
Blood Return
Blood Drainage
Bridge
Heat Exchanger
Servo-Regulation
Pump
Membrane Lung

ECMO PUMP CIRCUIT





Initiation and maintenance of ECMO

- Circuit setup
- Heparinisation
- Cannulation
- Flow:
  - Paediatric 100-150 ml/kg/min
  - Adult 80 – 100% cardiac output
- Monitoring

Haemodynamic support

- Inotropic drugs: Dopamine, Dobutamine, etc.
- In some cases: Noradrenaline may be needed because of low SVR. Blood pressure generated by ECMO depends upon ECMO flow and SVR.

$$MABP = Flow \times SVR$$

- Fluid replacement
- Blood component

Ventilatory management

- "Rest setting"
- Rate 10 bpm
- FiO_2 0.21
- PEEP 10
- PIP 20
- Increased ventilation setting may be used for VV ECMO or cardiac ECMO

Monitoring

- pO_2 60-80 mmHg
- pCO_2 40-45 mmHg
- pH 7.40
- ACT 180-250 sec. (vary from institution to institution), present 160-180 sec.
- Fluid intake and output should be balanced
- Respiratory tidal volume of 10ml/kg

Haematocrit

For VV ECMO:

Keep 40-45 %

For VA ECMO

Keep > 40%

Anticoagulation management

- Loading of heparin 100 units/kg/dose (70 units/kg/dose before cannulation
- Maintenance: 30 – 60 units/kg/hour
  - Add heparin 25 units/kg in 1ml of 0.9%NaCl or 5% D/W 50 ml
  - Start infusion when ACT < 350 sec.

Anticoagulation monitoring

- Activated clotting time (ACT)
- Use diatomaceous earth as the activator
- Required level 180-250 sec. (GOSH 170-200 sec.)
- Maintained by continuous heparin infusion

Anticoagulation monitoring

Cerebral monitoring

- Electroencephalography: periodically done in case of monitoring CNS function

Applications of ECMO

- Cardiopulmonary support
- Bridge to recovery
- Bridge to destination
- Bridge to bridge
- Bridge to transplantation

ECMO as a bridge to bridge

- ***"…Strategy of ECLS to implantable LVAD bridge to heart transplant*** **in adult patients who are in need of circulatory support and who are not initially candidates for other forms of mechanical support. The favorable results of this strategy support utilization of ECLS even in situations where myocardial recovery is thought to be unlikely."**

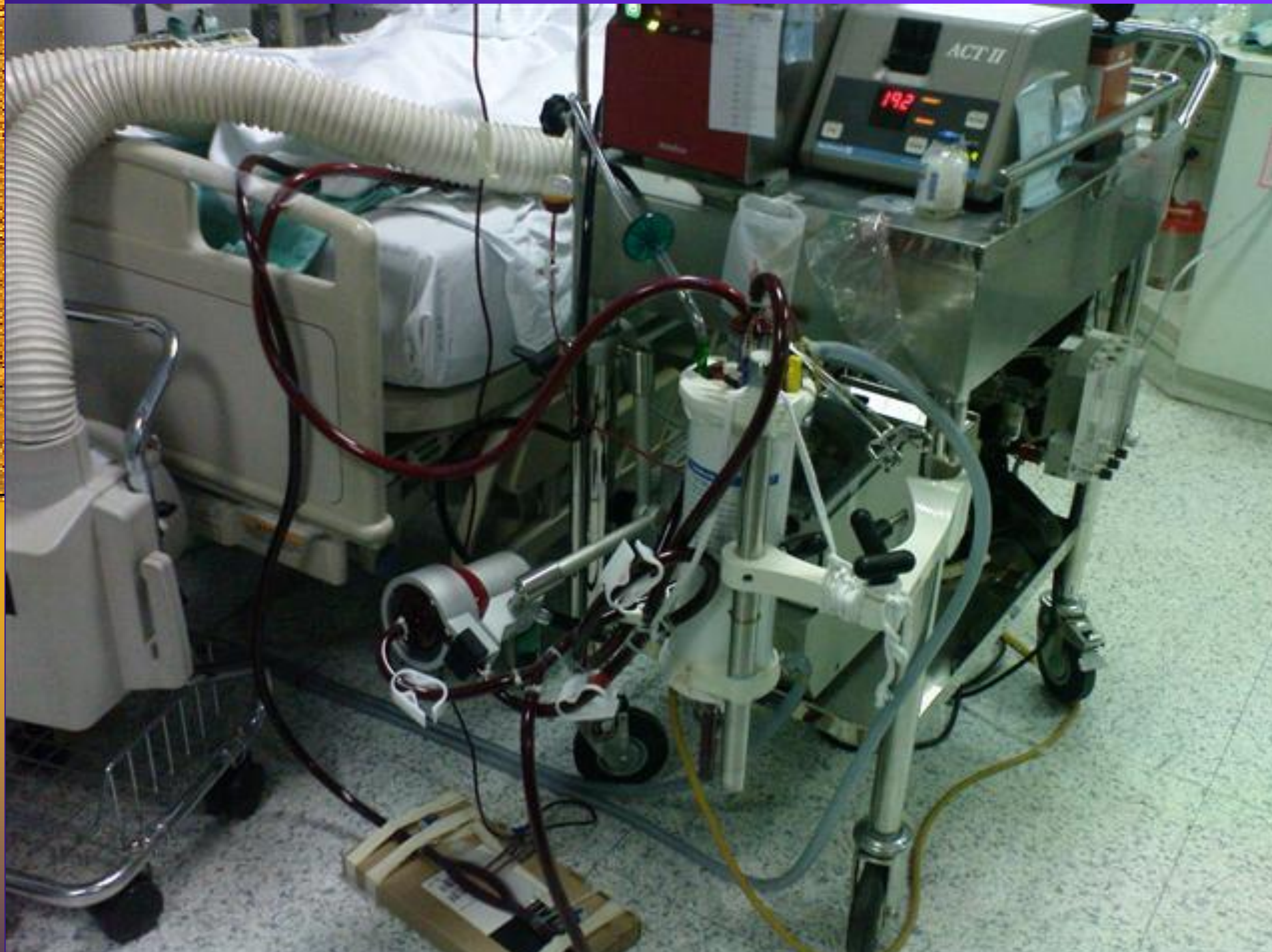
Francis D. Pagani, MD, PhD, Keith D. Aaronson, MD, Fresca Swaniker, MD, and Robert H. Bartlett, MD Ann Thorac Surg 2001;71:S77–81

Possible complications

- Pump Failure
- Decannulation
- Circuit Rupture
- Air Embolism
- Cardiac Arrest
- Oxygenator Failure

ECMO experience

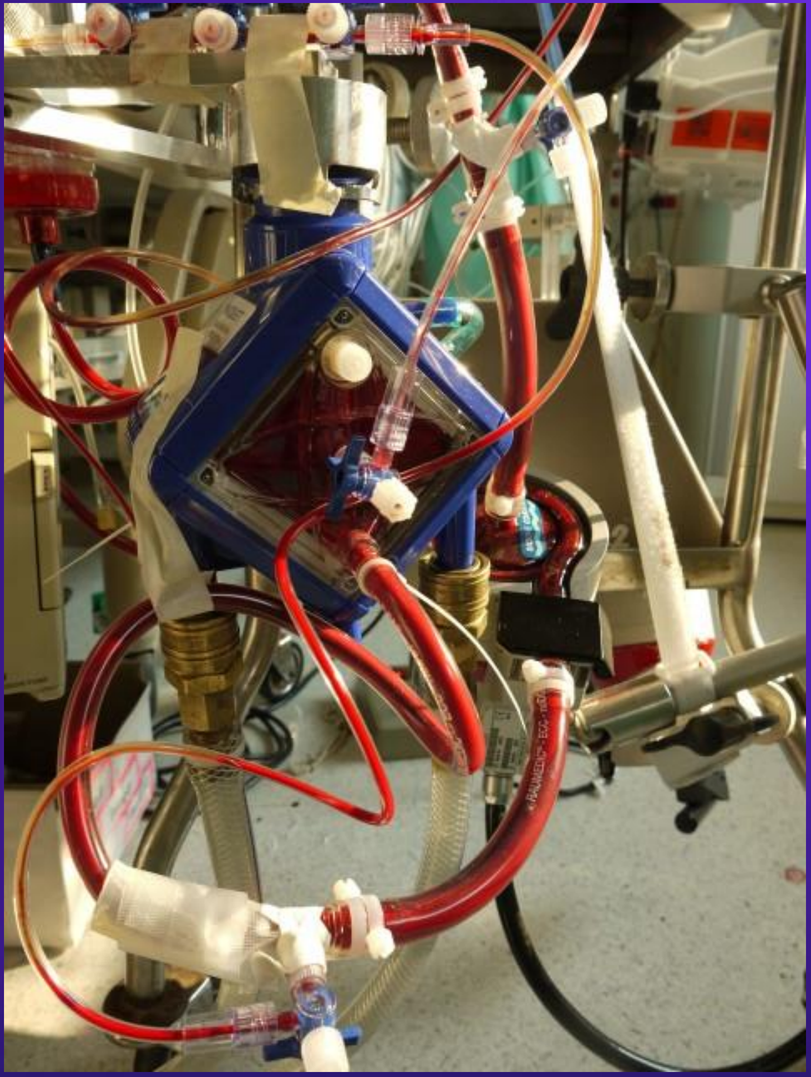
Experience at Ramathibodi


ACT II
192

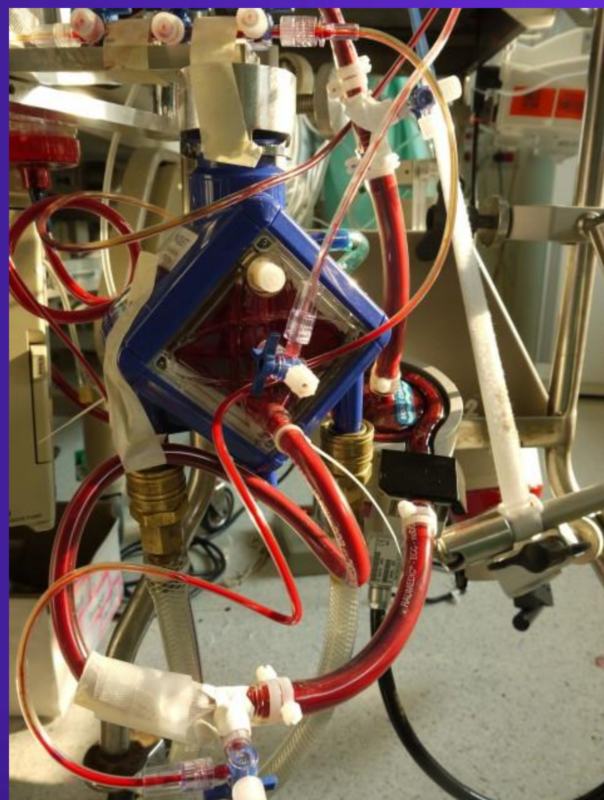


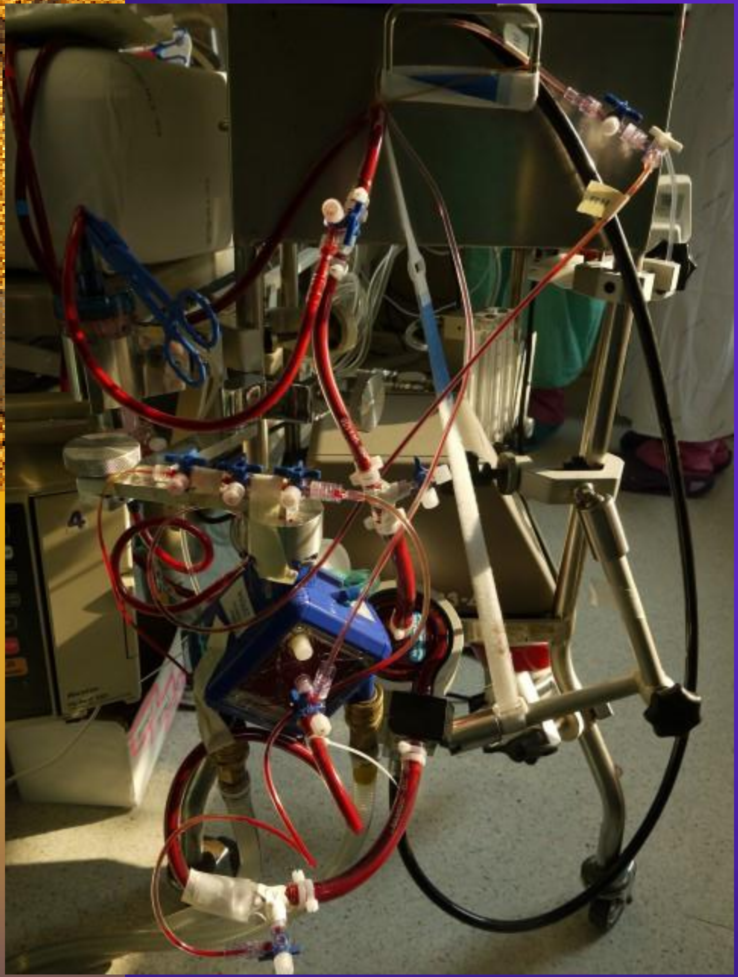


Recent case



Example





Current application and future

Pre-hospital ECMO cannulation

Future>>>


THANK YOU
FOR YOUR ATTENTION
MAHIDOL UNIVERSITY