ECMO

Extra Corporeal Membrane Oxygenation

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Chairman

Medanta – The Medicity

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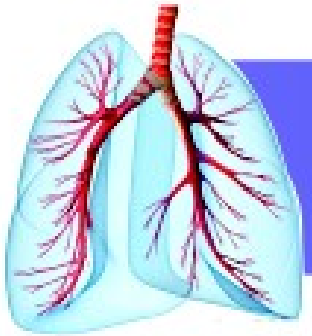
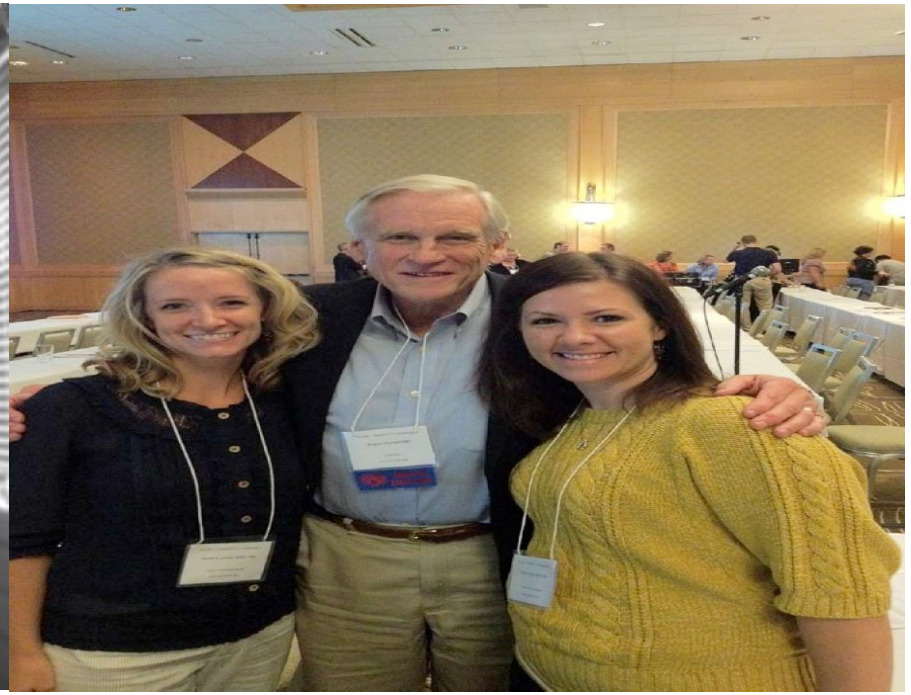
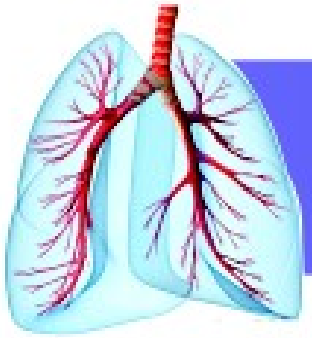


HISTORY OF ECMO

- **Artificial placenta:-** Callahan /Avery/ White
  - Important for development & refinement → mech/ surgical/ foundations subsequent success
- 1976 Dr. Bartlett → 1st neonatal ECMO survivor

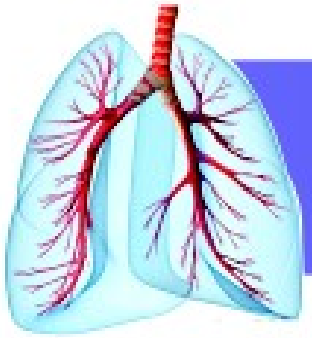


ECMO CENTRES OF INDIA



ECMO PHYSIOLOGY

- **Physiological Goals**
  - Drain venous blood
  - Improve Oxygen delivery
  - Remove CO2
  - Allow Aerobic metabolism with Lung rest
  - Return blood back via Vein (V-V) or Artery (V-A)



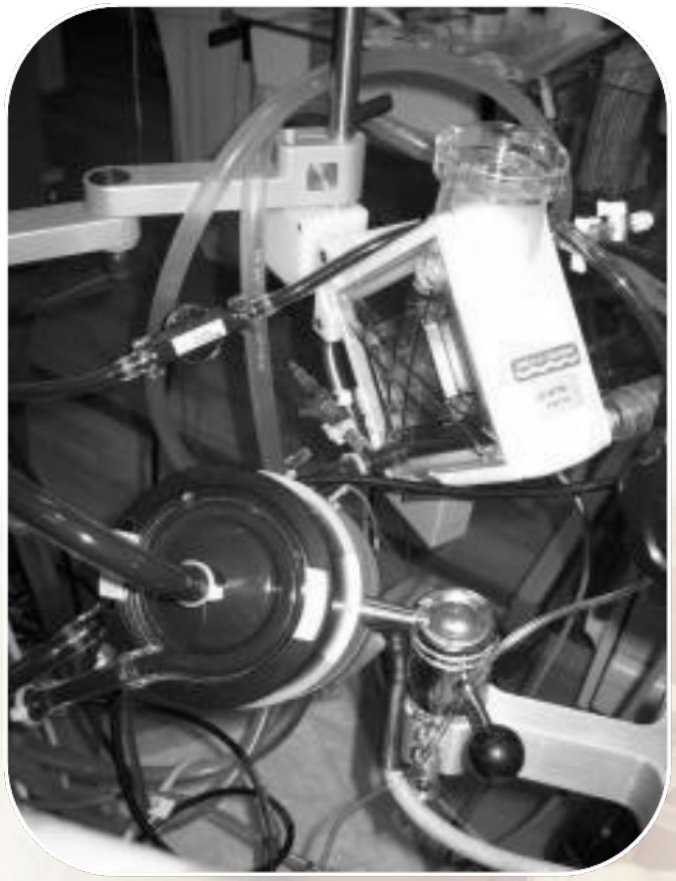
ECMO PRINCIPLE

- Desaturated blood is drained via a venous cannula
- CO_2 is removed, O_2 added through an "extracorporeal" device
- The blood is then returned to body circulation via another vein (VV ECMO) or artery (VA ECMO)
- Flow 80-100 ml/kg/min (vs. 2-3 ml/kg/min in CRRT)

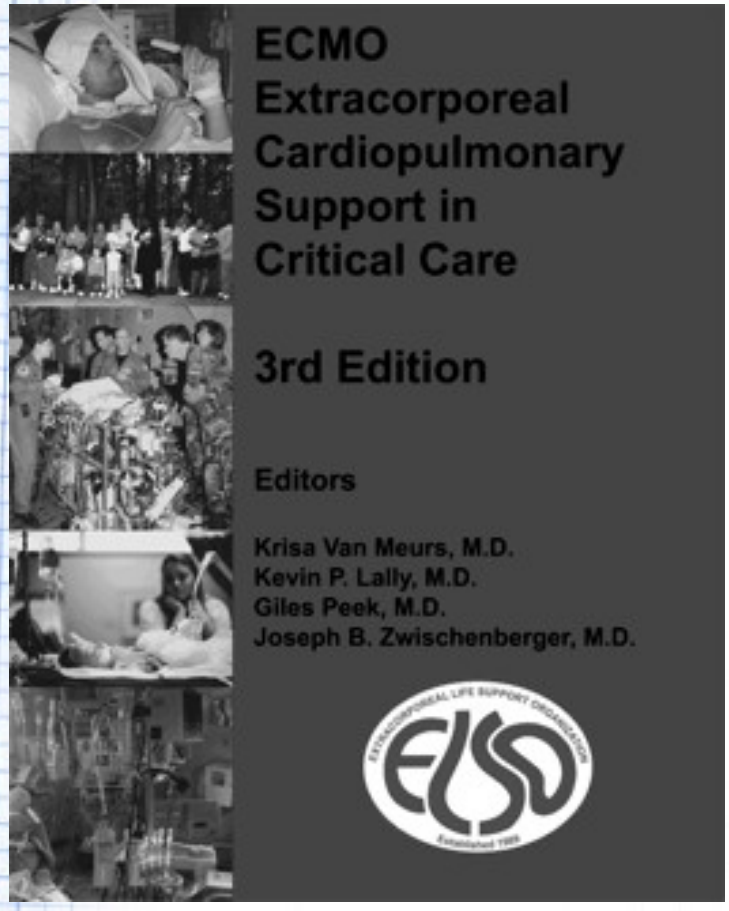
ECMO MECHANICS

ECMO BASICS

- **ECMO should be considered if the process is:**
  - Severe
  - Acute
  - Potentially reversible.



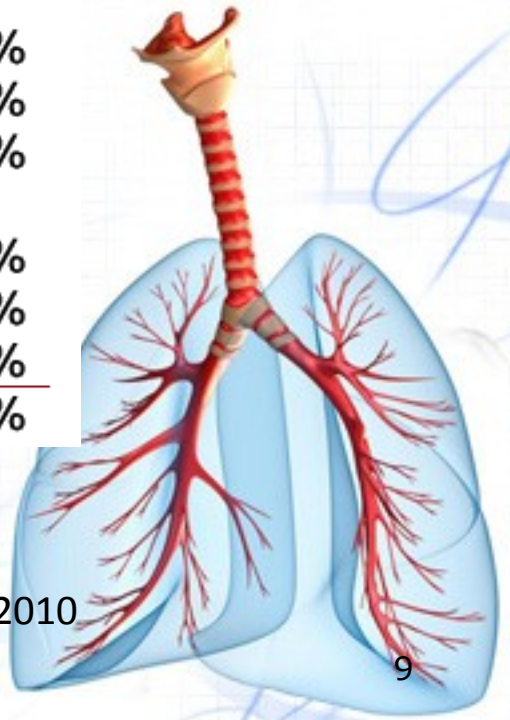
3 TYPES OF ECMO



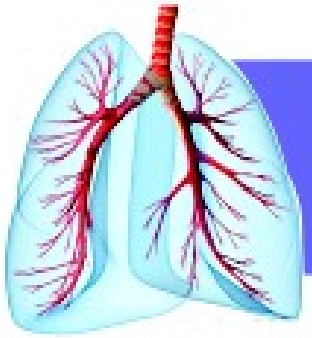
- Respiratory ECMO
- Cardiac ECMO
- “Rescue” ECMO

OVERALL PATIENT OUTCOMES

	Total	Surv ECLS		Surv to DC	
Neonatal					
Respiratory	23,558	19,964	85%	17,720	75%
Cardiac	3,909	2,338	60%	1,515	39%
ECPR	537	340	63%	203	38%
Pediatric					
Respiratory	4,376	2,831	65%	2,431	56%
Cardiac	4,776	2,995	63%	2,250	47%
ECPR	1,003	528	53%	387	39%
Adult					
Respiratory	1,860	1,140	61%	968	52%
Cardiac	1,131	541	48%	379	34%
ECPR	408	147	36%	109	27%
Total	41,558	30,824	74%	25,962	62%



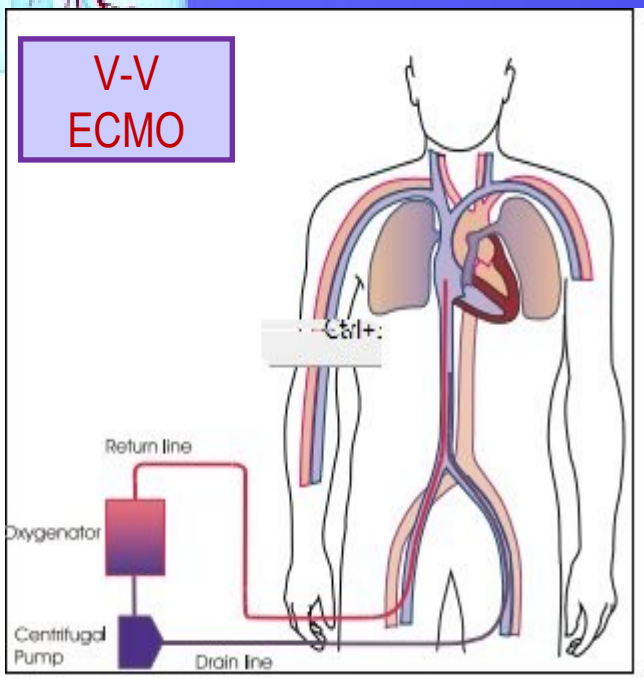
- ELSO Registry, 2010

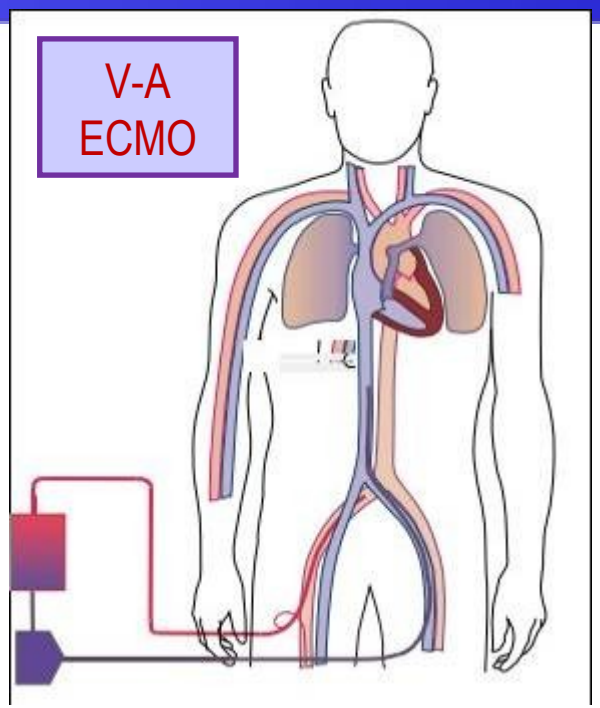


TWO TYPES OF ECMO

- **Veno-arterial bypass** - supports the heart and lungs
  - Requires two cannulae-one in jugular vein and one in the carotid artery
- **Veno-venous bypass** – supports the lungs only
  - Requires one cannula- jugular vein

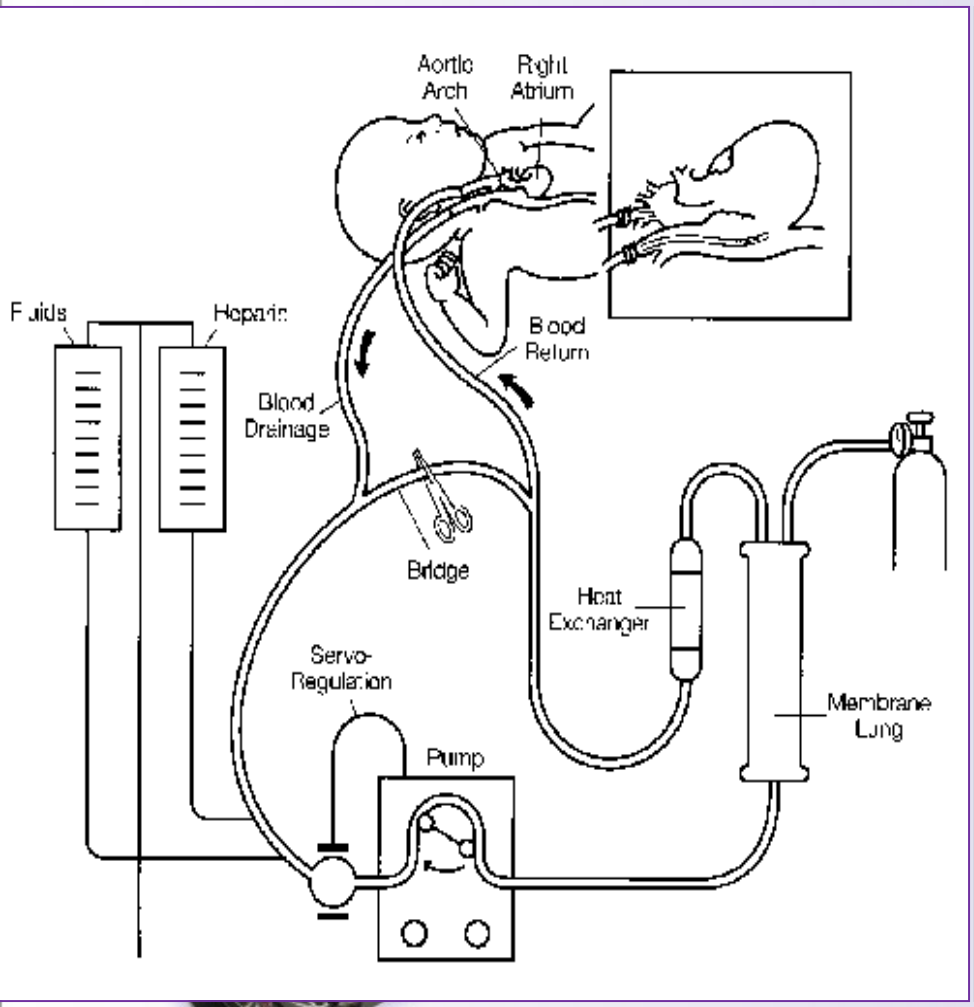
TYPES OF ECMO



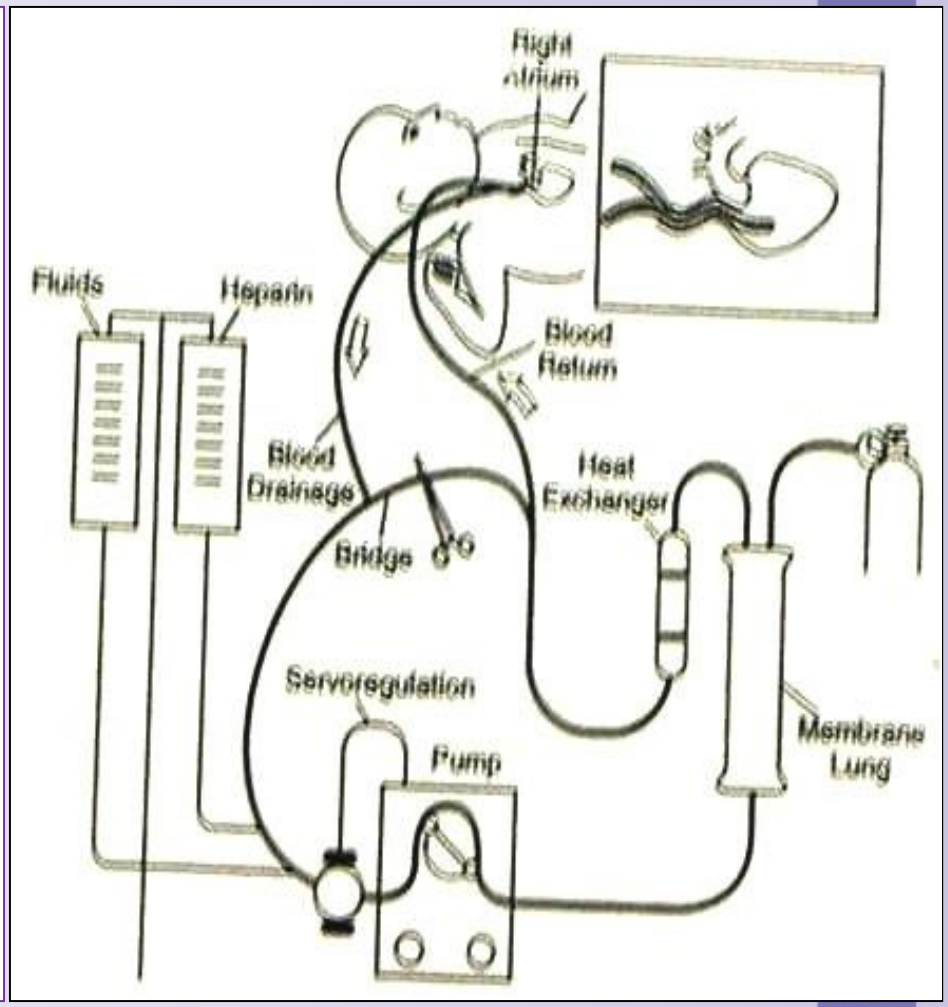


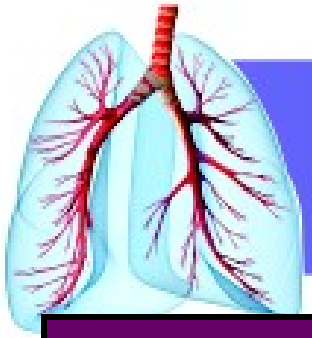
	Bad lung good Heart	Good lung Bad heart	Bad lung Bad heart
V-V	√	X	X
V-A peripheral	X	√	√
V-A Central	√ (not required)	√	√

VA ECMO



VV ECMO

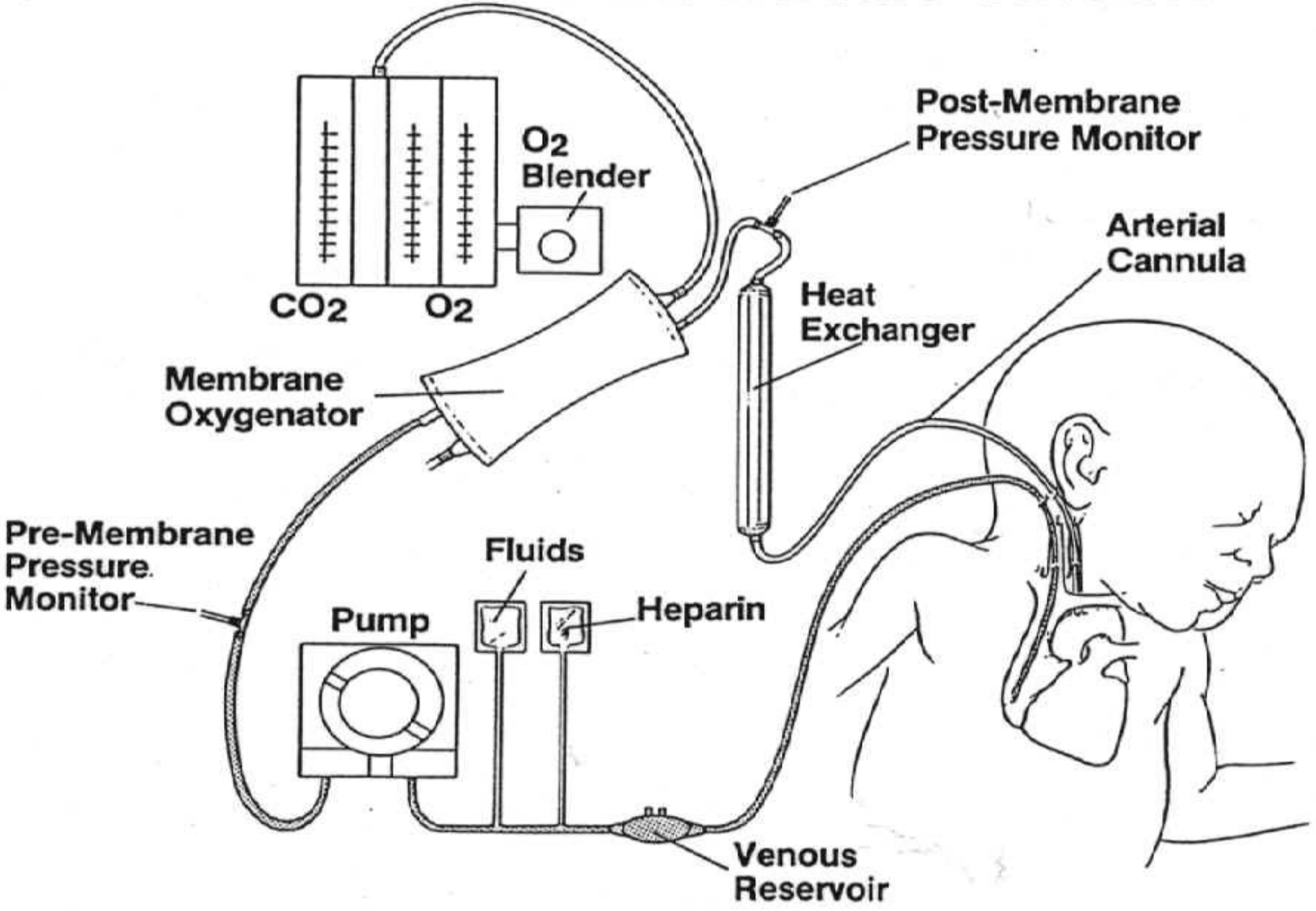




ECMO TYPES

Property	VA ECMO	VV ECMO
Cannulation site	IJV/FV and RCC/Ax/FA/Ao	IJV alone/ IJV-FV/ FV-FV/Saph-saph/RA
PaO2	60-150 mmHg	45-80 mmHg
Indicator of O2 sufficiency	Mixed ven sat or PaO2	Combination of SaO2, PaO2, cerebral ven sat & pre membr sat trend
Cardiac effect	↓ preload; ↑afterload; pulse pr ↓; coronary oxyg by LV blood; `Cardiac stun`	Negligible effects; may improve coronary oxyg; may reduce RV afterload
O2 delivery capacity	High	Moderate. ↑cephalad drain
Circulatory support	Partial to complete	Indirect: ↑ delivery of O2 to coronary & pulm circ

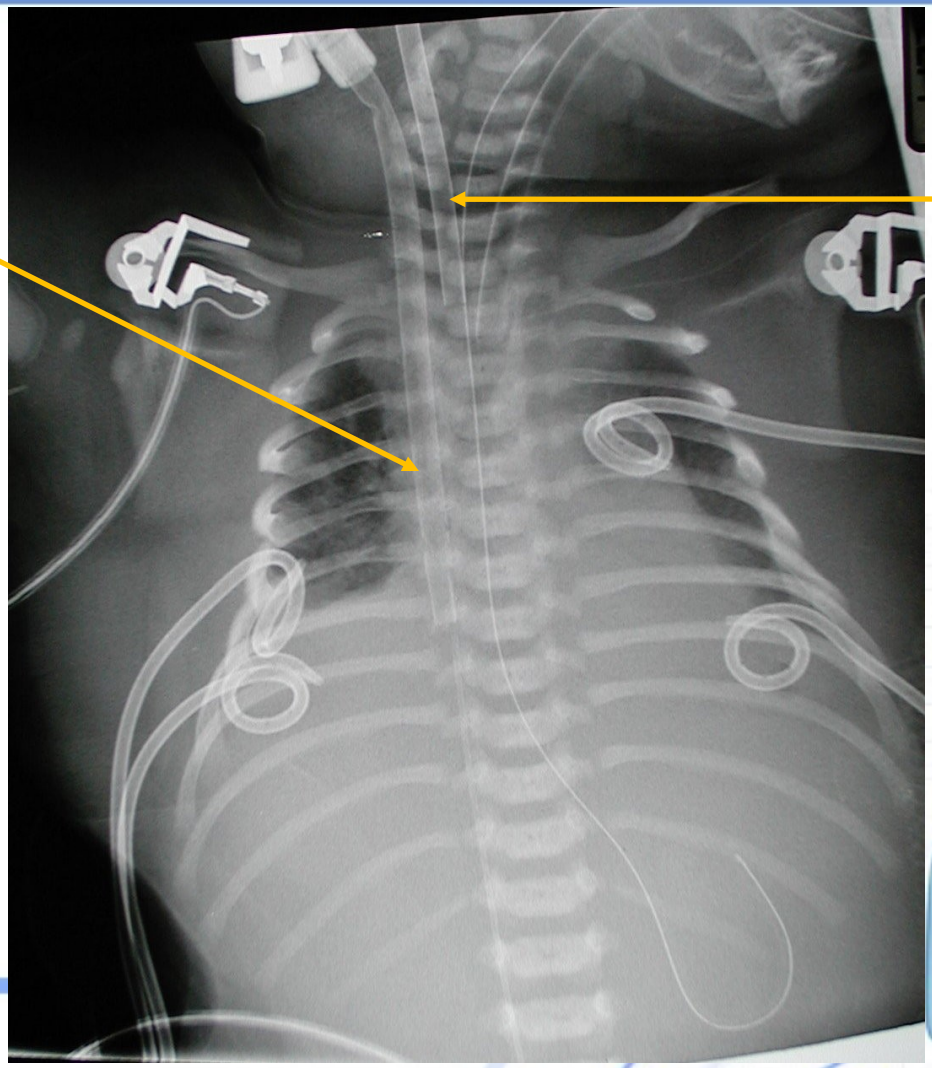
VENOARTERIAL ECMO CIRCUIT



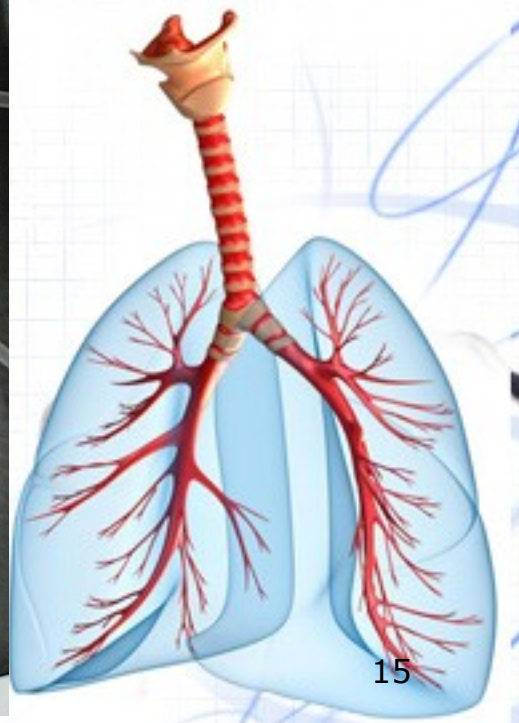
ECMO ANATOMY

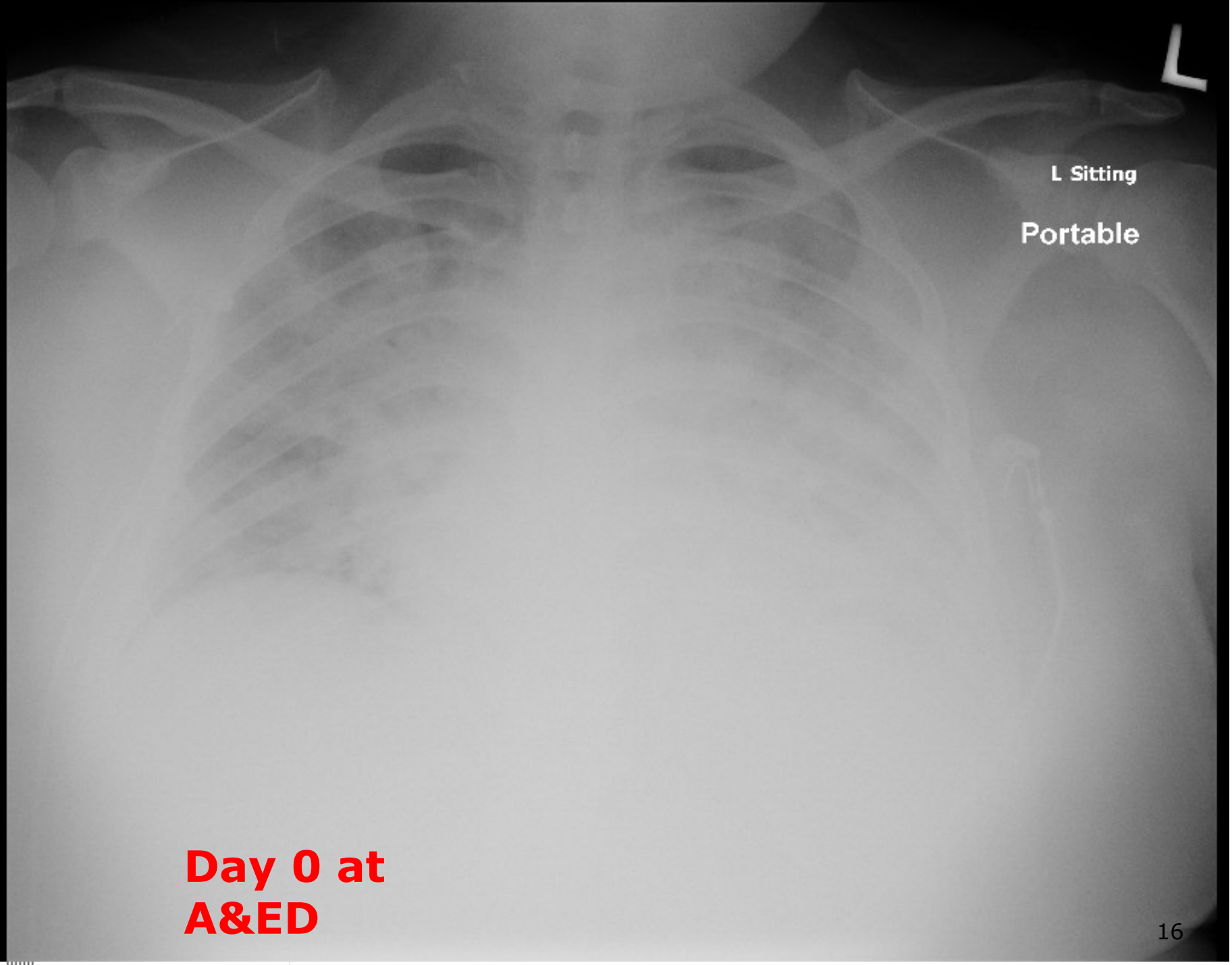
VENO-ARTERIAL CANNULATION

Venous Cannula

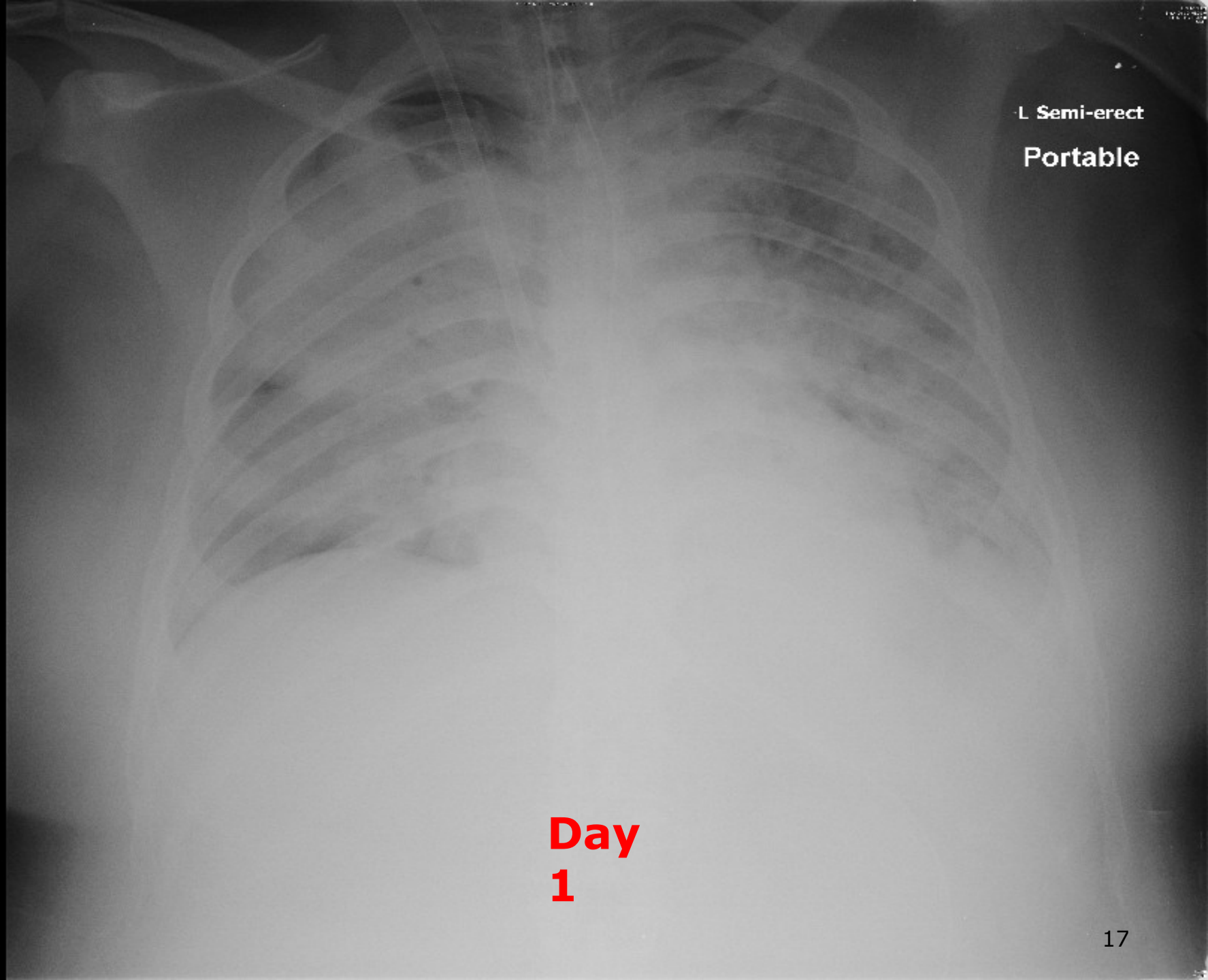


Arterial Cannula

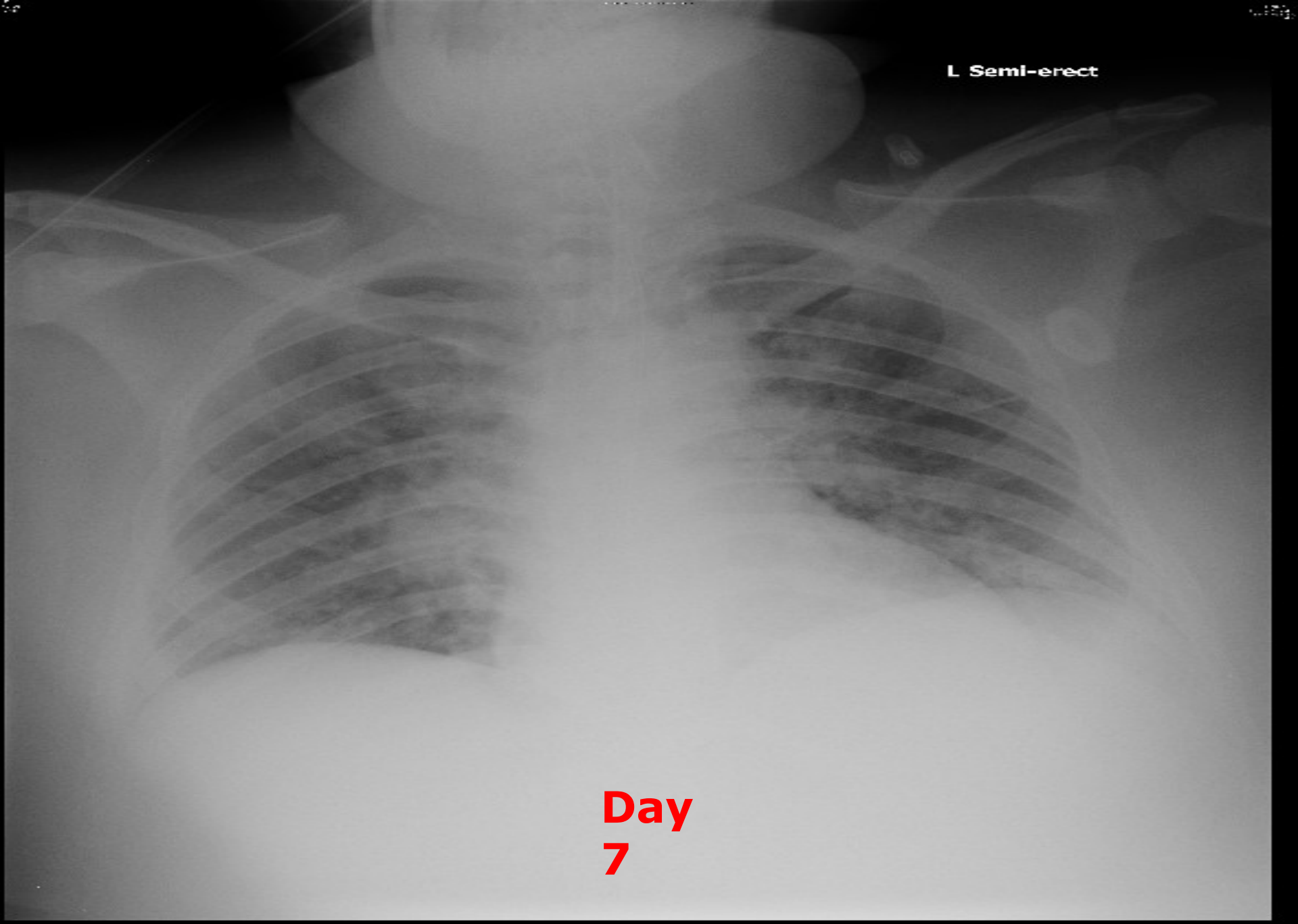




Day 0 at A&ED



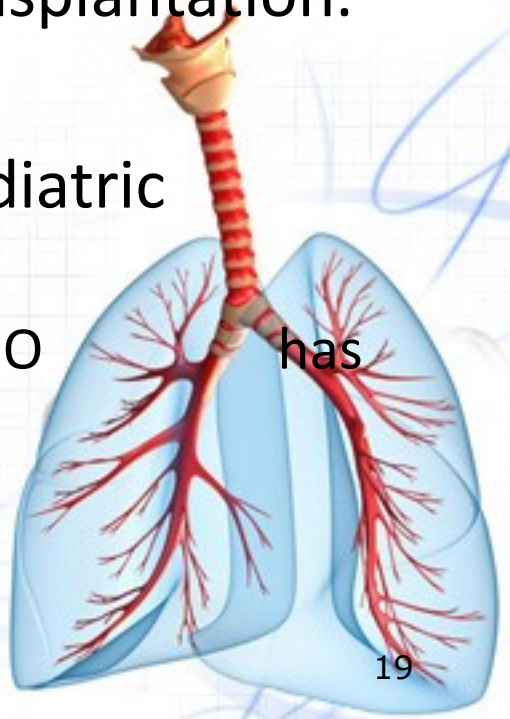
Day 1

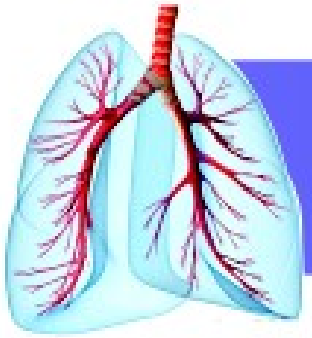

L Semi-erect
Day
7

INDICATIONS – RESPIRATORY FAILURE

- Adult respiratory distress syndrome (ARDS)
- Pneumonia
- Trauma
- Primary graft failure following lung transplantation.

- ECMO is also used for neonatal and pediatric respiratory support
  - This is where most of the research on ECMO has been done



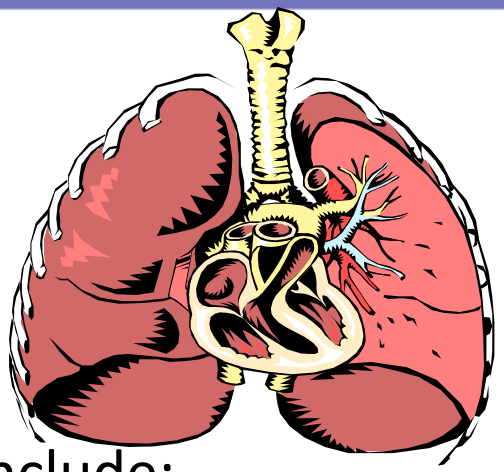


INDICATIONS OF ECMO

The need for ECMO is when a patient who has received appropriate medical management has:

- a PaO2 of 50-60mmHg, when the PIP is >35cmH20
- FiO2 is 100% for conventional ventilation
- without improvement of oxygenation while on high frequency ventilation over a six hour period.

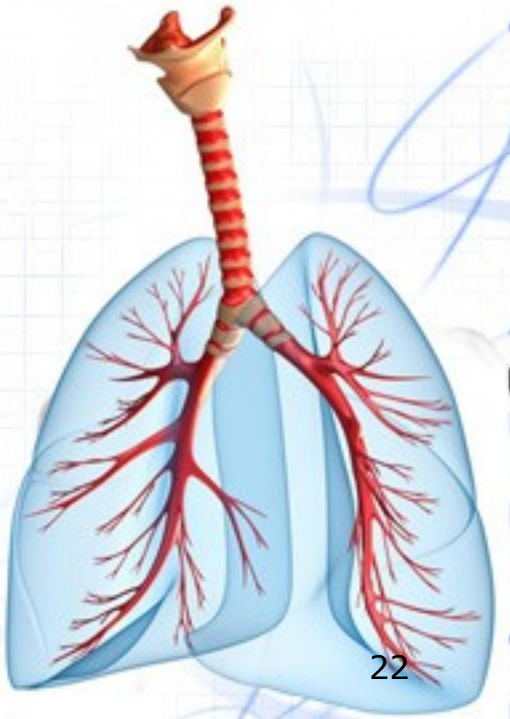
TREATMENT FOR CHILDREN:



- Hyaline membrane disease
- Meconium Aspiration
- Persistant Fetal Circulation
- Congenital Diaphragmatic Hernia
- Cardiac Anomalies
- Types of patients commonly seen on ECMO include:
  - Meconium Aspiration
  - Congenital Diaphragmatic Hernia
  - Persistent Pulmonary Hypertension
  - Respiratory Distress Syndrome
  - Sepsis
  - Aspiration
  - Pneumonia
  - Myocarditis
  - Electrolyte disturbances
  - Congenital Heart Disease (before or after cardiac surgery)

TREATMENT FOR ADULTS

- Adult Respiratory Distress Syndrome (ARDS)
- Non-necrotizing pneumonias
- Pulmonary contusion
- Other reversible respiratory
- TRALI
- Bridge to lung transplant
- Sepsis



CONTRAINDICATIONS

ntracerebral hemorrhage

evere brain damage

ultiple congenital anomalies

rreversible brain damage

eight <2.0Kg

ast Contraindications

eurological compromise

ecrotizing Pneumonia

ultiple organ failure

etastatic disease

ajor CNS injury

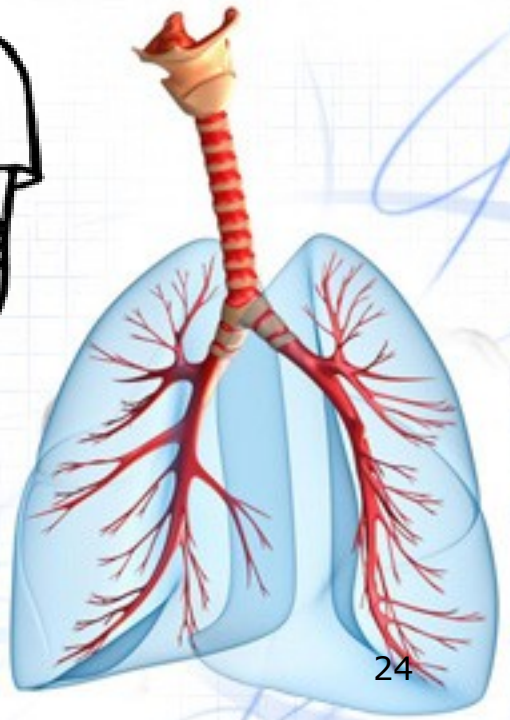
estational age <34 weeks

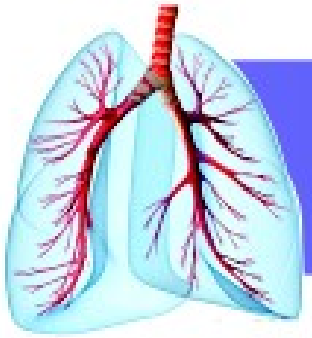
verwhelming Sepsis

arental Refusal

ECMO CONTRAINDICATIONS

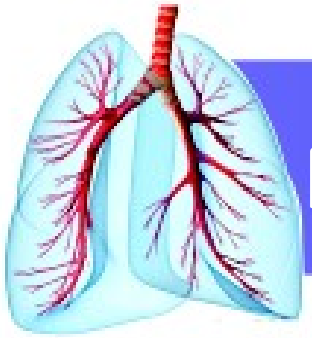
- **ONLY Absolute**
  - Do not resuscitate?





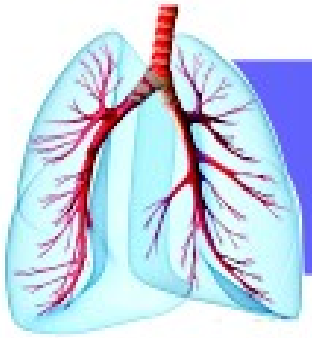
PATIENT SELECTION

- Must be a reversible process.
- Patient should be placed on ECMO within first 5 days.
- Have an exit strategy.



PRELIMINARY DIAGNOSTIC STUDIES

- Head Ultrasound
- Coagulation Status
- Platelet Count
- Calcium and Electrolyte levels
- White Blood Cell Count
- Hemoglobin and Hematocrit levels
- Blood type and Cross



ANTICOAGULATION

- Systemic heparin
- Bolus heparin at cannulation
  - 100 units/kg
- Continuous heparin gtt
  - 20-50 units/kg/hour

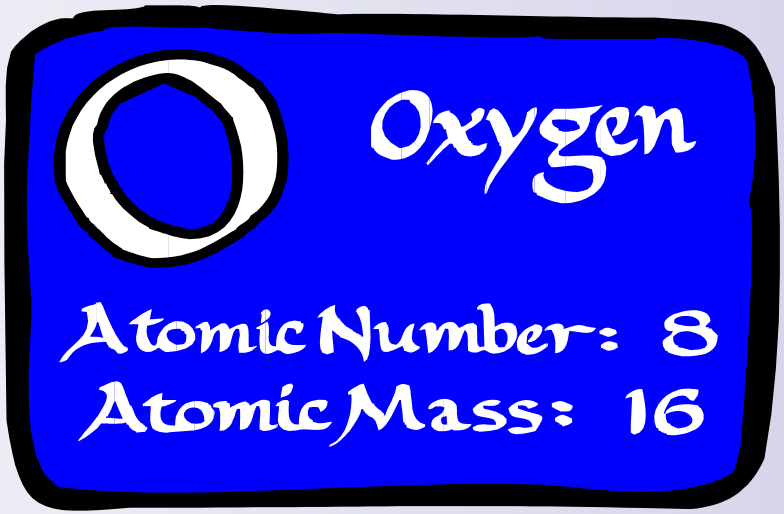
- Procoagulants factors
- Anticoagulant factors

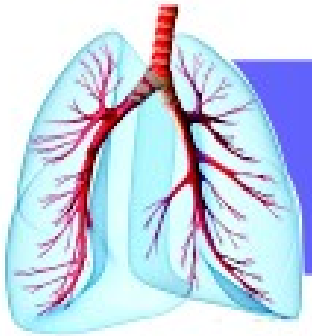
POINT OF CARE TEG AND ANTICOAGULATION IN ECMO

- TEG capabilities allow one to **monitor platelet function, clotting factors, and fibrinolysis.**
- Specifically, with regard to neonatal ECMO, Zavadil and colleagues **suggest factors other than heparin contribute to the derangement in hemostasis, and the interpretation of TEG data is invaluable.**
- Applying an algorithm including TEG enables physicians to achieve a more accurate reflection of the in vivo physiology of anticoagulation.
- A novel method utilizing a **TEG assay with tissue factor**
- **Kaolin (TEG TF/K)** more rapidly and accurately monitors heparin anticoagulation.

ECMO TUBING CONNECTION TO THE PATIENT

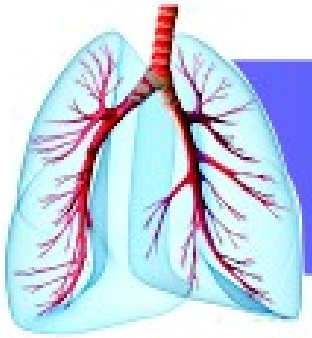
- Limiting the duration of ECMO to <30 days due to increased risks of complications after approximately fourteen days of therapy.





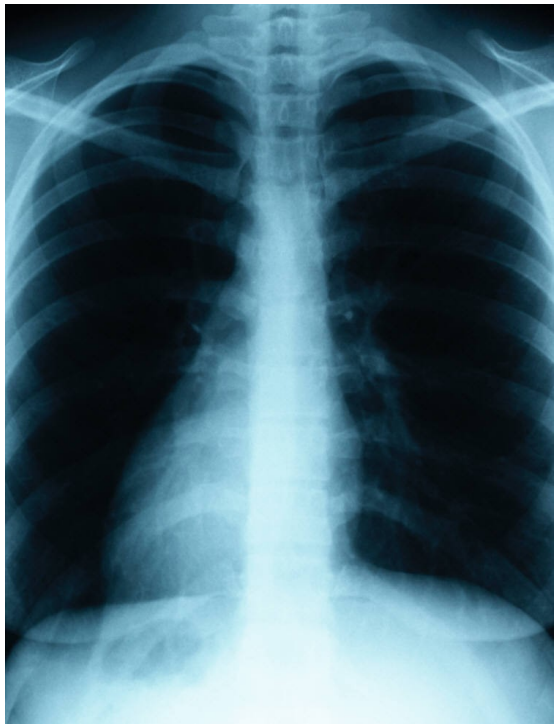
POTENTIAL RISKS

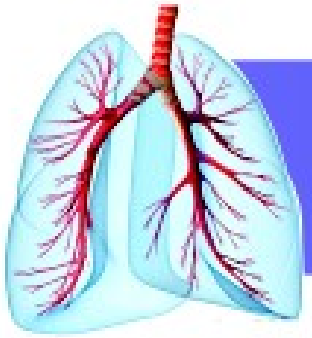
- Insertion of a tube into a blood vessel has an increased risk of infection.
- Brain damage from head bleed
- Surgical site bleeding
- Pneumothorax
- Hypertension
- Cardiac Dysrhythmias
- Abnormal creatin and bilirubin values
- Intraventricular hemorrhage
- Air in circuit
- Pump malfunction
- Clots in the circuits
- Pump malfunction
- Heat exchanger malfuntion



POTENTIAL BENEFITS

- Being on ECMO will rest the lungs and heart so that there is an increased survival rate.



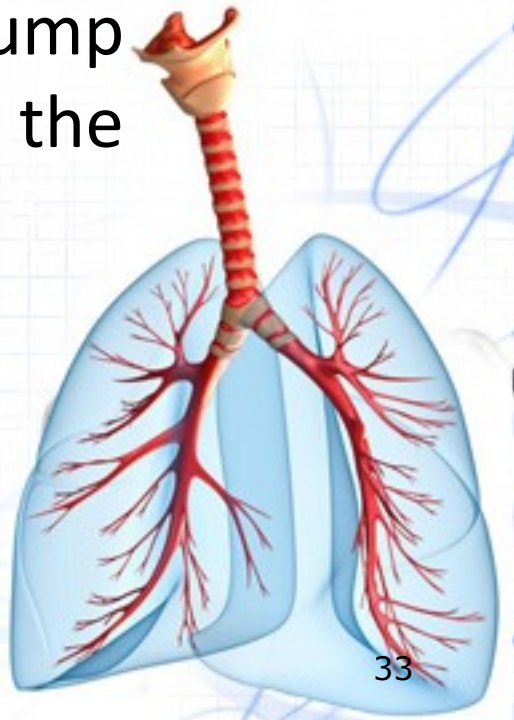


MEDICATIONS

- Fentanyl 25-30 micrograms/kg
- Atropine 0.01 mg/kg
- Neuromuscular blocking agent
- Heparin 100 units/kg bolus
  - Needed even if continuous heparin gtt will not be used
- Ca
- Volume
  - NS, PRBC, FFP, Albumin
  - Prime oxygenated circuit blood

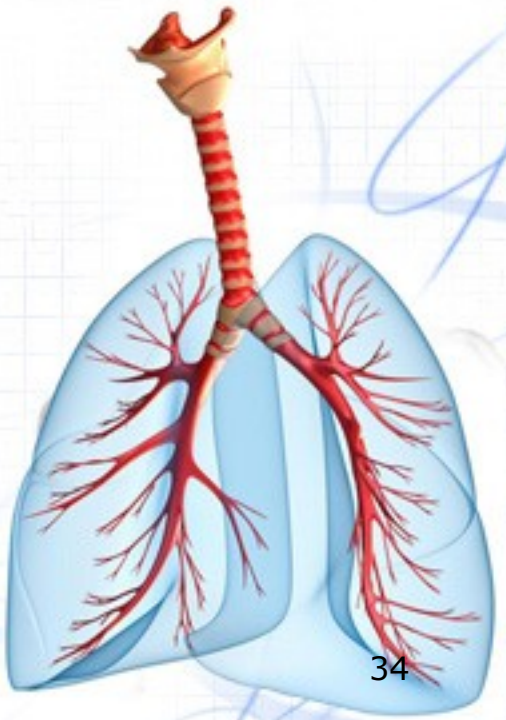
WEANING PARAMETERS

- A trial period without ECMO when the patient demonstrates adequate gas exchange and is on reasonable ventilator settings and tolerates a pump flow of 10-20mL/kg/min with the minimum of 200 mL/min.



WEANING OF ECMO

- Assess pulmonary status
  - Compliance -
    - Vt with set Pmax, PEEP
    - Typical maximal vent setting
      - Pmax 30
      - RR 35-40
      - FiO2 50%
      - HFOV
  - Pulmonary hypertension
    - Cardiac echo
    - pre-post ductal saturations



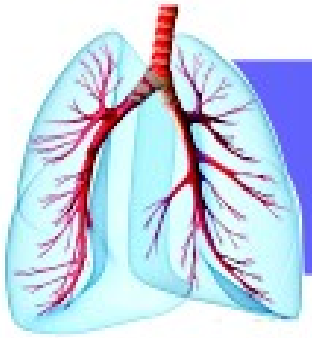
RECOVERY AND DECANNULATION

- Adequate gas exchange
  - PIP <30
  - PEEP<7
  - Rate <35-40
  - FiO2<50%
- Adequate cardiac output and BP
  - Cardiac echo

Zapol, : (NIH Trial) (VA ECMO +ventilation and ventilation only) Severe ARF. A Randomized Prospective Study.

- 90 patients from across the US between 1974 and 1977.
- No benefit shown with survival of <10% in both groups
- Issues with the study:
  - Variety of techniques used, primitive ECMO design
  - Limited experience with ECMO and IPPV
  - During ECMO, lungs were not put to rest
  - High bleeding complications

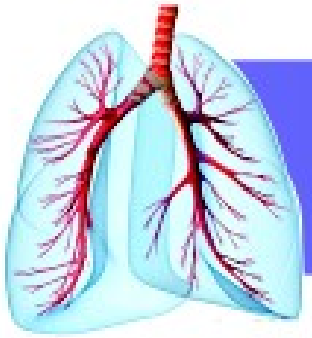
JAMA 1979:242:2193-6



MORRIS ET AL. PCIRV VS $ECCO_2R$

- 40 patients with severe ARDS enrolled
- 33% survival in 21 patients $ECCO_2R$ + LFPPV
- 42% survival in 19 patients PCIRV
- P = 0.8
- 7/19 cases on $ECCO_2R$ with bleeding resulting in premature discontinuation of Rx
- High pressure ventilation used before and $ECCO_2R$ with peak inspiratory pressure 45-50cm H_2O

AM J RESPIR CRIT CARE MED 1994;149:295-305



CESAR STUDY

CONVENTIONAL VENTILATION OR ECMO FOR SEVERE ADULT RESPIRATORY FAILURE

- Single ECMO centre at Glenfield Hospital, UK
- Survival without severe disability (confined to bed, or unable to dress/wash oneself) by 6 months
  - ECMO: 57 in 90 patients (63%)
  - Conventional ventilation: 41 in 87 patients (47%)
  - Relative risk reduction in favour of ECMO

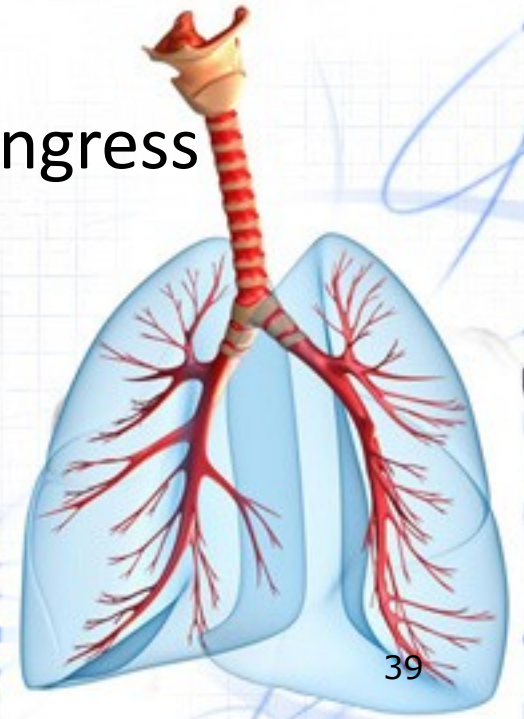
    0.69 (0.05–0.97; P = 0.03)
  - NNT to save one life without severe disability is 6

LANCET 2009, 374:1351-63

CESAR

- Conventional Ventilation or ECMO for Severe Adult Respiratory Failure

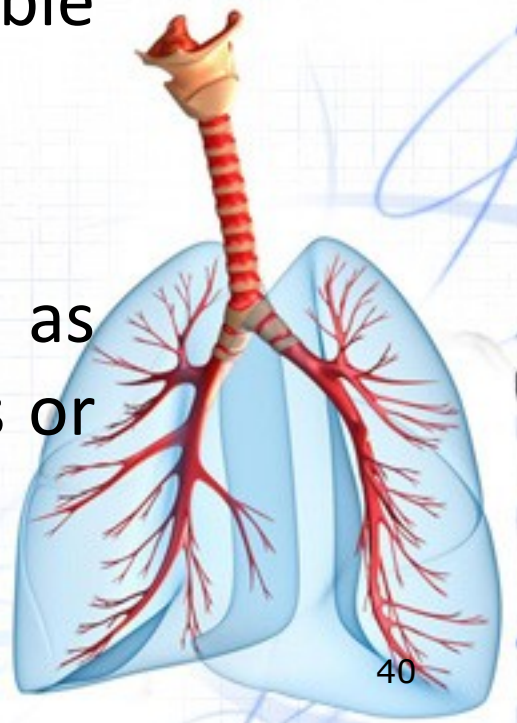
- Preliminary results released at 37th Society of Critical Care Medicine Congress in Honolulu February 2008



CESAR

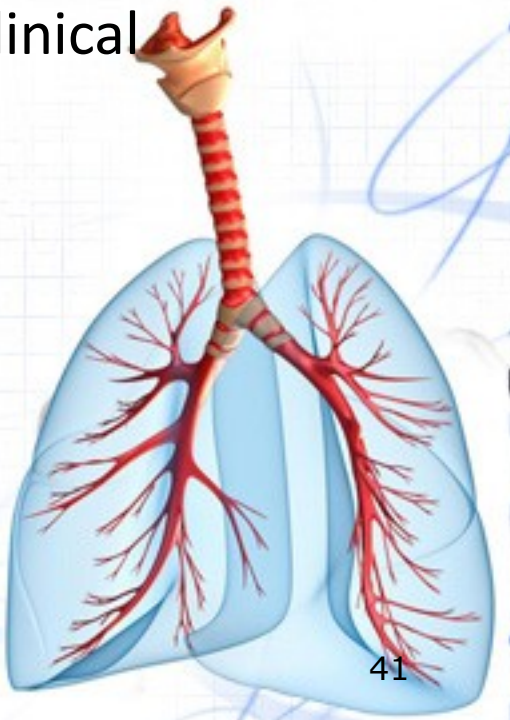
- Randomized controlled trial to assess the impact of ECMO on survival without severe disability by 6 months in patients with potentially reversible respiratory failure

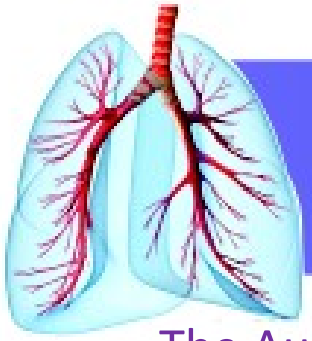
- Severe disability was defined as confined to bed and unable to dress or wash oneself



CESAR

- Conducted from 2001-2006
- Adults were randomized either to VV ECMO at Glenfield Hospital, Leicester, England (90 patients) or continuing conventional care at referral hospitals (90 patients).
- The conventional group underwent standard clinical practice in the UK
  - Conventional Ventilator
- ECMO
  - 57 of 90 met primary endpoint
- Conventional ventilation group
  - 41 of 87 met primary endpoint





ECMO for 2009 Influenza A(H1N1) Acute Respiratory Distress Syndrome

The Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators
JAMA. 2009;302(17):1888-1895. Published online October 12, 2009(doi:10.1001/jama.2009.1535)

- During winter 2009 (1 June 2009 to 31 August 2009), Australia & New Zealand ICUs
- 68(34%) required ECMO out of 133 patients with IPPV
- For patients given ECMO
  - 48/68 (71%) survived ICU
    - 32/68 (47%) survived hospital
    - 16/68 (24%) still in hospital
  - 6/68 (9%) still in ICU
  - 14/68 (21%) died

JAMA. 2009;302(17):1888-1895. doi:10.1001/jama.2009.1535.

MURRAY SCORE
= AVERAGE SCORE OF ALL 4 PARAMETERS

Parameter / Score	0	1	2	3	4
PaO_2/FiO_2 (On 100% Oxygen)	≥300mmHg ≥40kPa	225-299 30-40	175-224 23-30	100-174 13-23	<100 <13
CXR	normal	1 point per quadrant infiltrated			
PEEP(cmH_2O)	≤5	6-8	9-11	12-14	≥15
Compliance (ml/cmH_2O)	≥80	60-79	40-59	20-39	≤19

CASE REPORT

The first novel influenza A (H1N1) fatality despite antiviral treatment and extracorporeal membrane oxygenation in Hong Kong

- Although extra corporeal membrane oxygenation is an effective means of supporting patients with refractory hypoxaemia on high mechenical ventilatory support, it is labour intensive and technically demanding.

- We also discussed the challenges face when managing this case

Hong Kong Med J 2009;15:381-4

ECMO FOR MECONIUM ASPIRATION

- 40% of infants with MAS treated with inhaled NO fail to respond and require bypass.
- 35% of ECMO patients are with MAS.
- Survival rate after ECMO 93-100%.

ISHLT Links
April 2012
Vol. 3 Issue 11

ECMO Use as a Bridge to Pediatric Lung Transplantation

Christian Benden MD
St Vincent's Hospital, Sydney, Australia

- The largest pediatric lung transplant program in the world, puri et al demonstrated that ECMO use before or after lung transplantation is associated with a significant morbidity and mortality in children requiring peri-operative ECMO support
- Children placed on venovenous (VV) compared to venoarterial (VA) ECMO had a better chance of overall survival, in particular, if weaned off ECMO prior to transplantation.
- The authors concluded to de-list patients in the future if ecmo was instituted for respiratory failure.

(ISHLT April 2012, vol. 3; issue 11)

Initial Experience With Single Cannulation for Venovenous Extracorporeal Oxygenation in Adults

Christian A. Bermudez, MD, Rodolfo V. Rocha, MD, Penny L. Sappington, MD, Yoshiya Toyoda, MD, PhD, Holt N. Murray, MD, and Arthur J. Boujoukos, MD

Heart, Lung, and Esophageal Surgery Institute, and Department of Critical Care Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

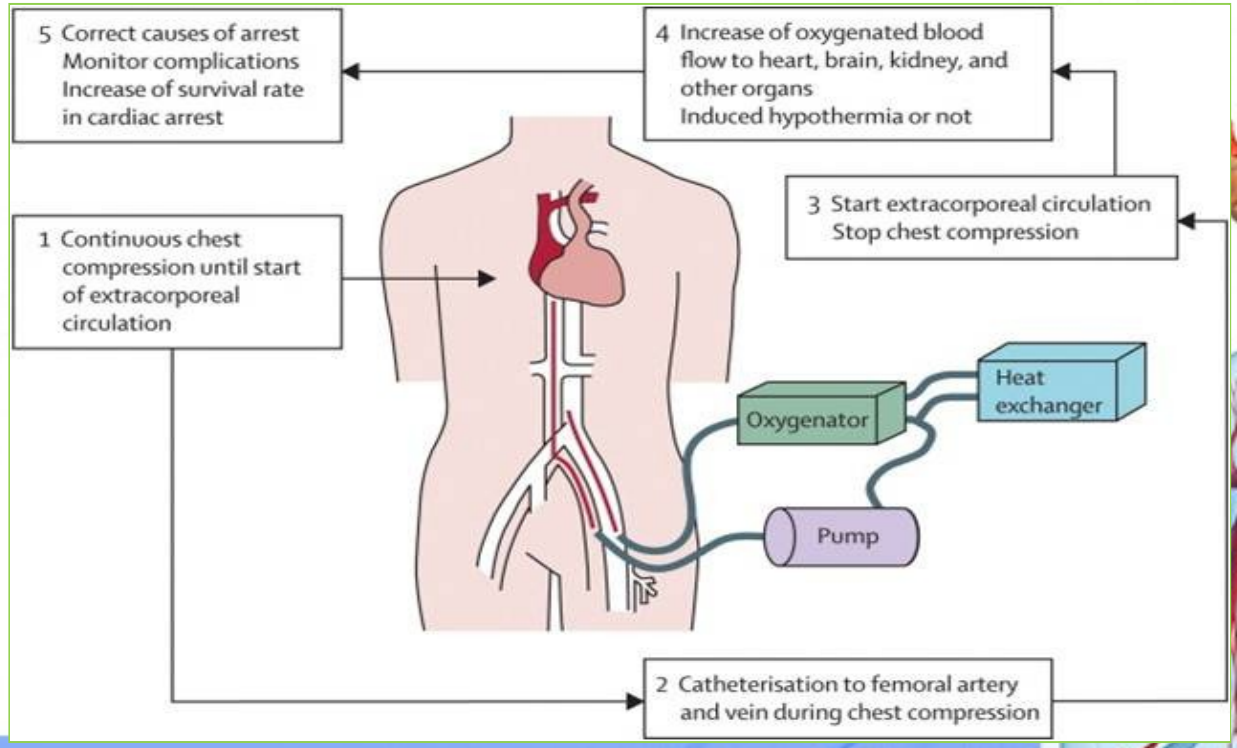
- Bermudez et. al. supports single-venous cannulation in venovenous extracorporeal membrane oxygenation as a promising technique.

- Excellent alternative to current cannulation strategies in patients requiring prolonged support and specifically for those considered for a bridge-to-lung transplantation.

(Ann Thorac Surg 2010; 90: 991-5)

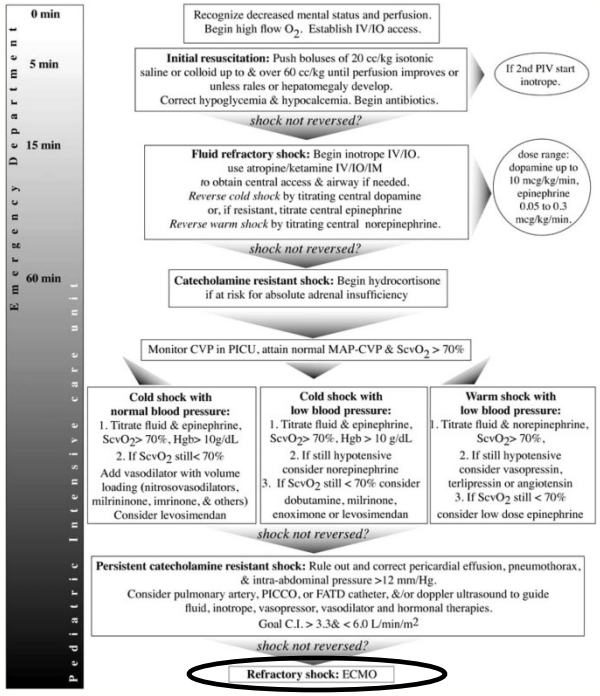
ECPR – EXTRACORPOREAL CARDIOPULMONARY RESUSCITATION

- CPR is not a contraindication for ECMO
- End organ perfusion may be better post CPR in infants treated with ECMO.

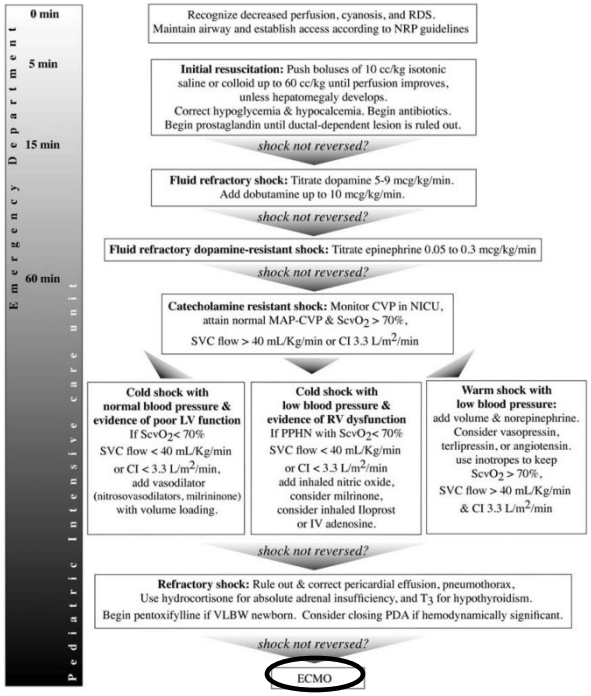


SEPSIS AND ECMO

Infants and Children

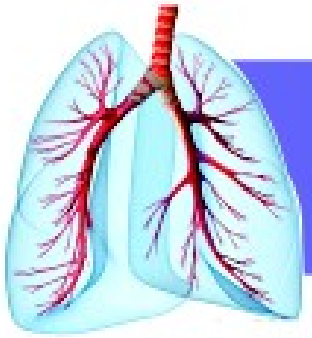


Neonates



Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine*

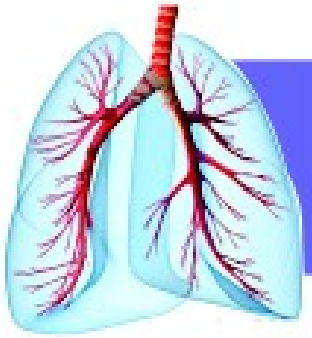
Joe Brierley, MD; Joseph A. Carcillo, MD; Karen Choong, MD; Tim Cornell, MD; Allan DeCaen, MD; Andreas Deymann, MD; Allan Doctor, MD; Alan Davis, MD; John Duff, MD; Marc-Andre Dugas, MD;
Alan Duncan, MD; Barry Evans, MD; Jonathan Feldman, MD; Kathryn Felmet, MD; Gene Fisher, MD; Lorry Frankel, MD; Howard Jeffries, MD; Bruce Greenwald, MD; Juan Gutierrez, MD;
Mark Hall, MD; Yong Y. Han, MD; James Hanson, MD; Jan Hazelzet, MD; Lynn Hernan, MD; Jane Kiff, MD; Niranjan Kissoon, MD; Alexander Kon, MD; Jose Irazusta, MD; John Lin, MD; Angie Lorts, MD;
Michelle Mariscalco, MD; Renuka Mehta, MD; Simon Nadel, MD; Trung Nguyen, MD; Carol Nicholson, MD; Mark Peters, MD; Regina Okhuysen-Cawley, MD; Tom Poulton, MD; Monica Relves, MD; Agustin Rodriguez, MD; Ranna Rozenfeld, MD; Eduardo Schnitzler, MD; Tom Shanley, MD; Sara Skache, MD; Peter Skippen, MD; Adalberto Torres, MD; Bettina von Dessauer, MD; Jacki Weingarten, MD; Timothy Yeh, MD; Arno Zaritsky, MD; Bonnie Stojadinovic, MD; Jerry Zimmerman, MD; Aaron Zuckerberg, MD



ECMO IN SEPSIS

- Initially, sepsis contraindication to ECMO
- 1990's multiple studies showed ECMO effective in sepsis
- Today VA remains primary mode of ECMO
- VV reserved for hemodynamic stability

- Few reports of VV ECMO and sepsis



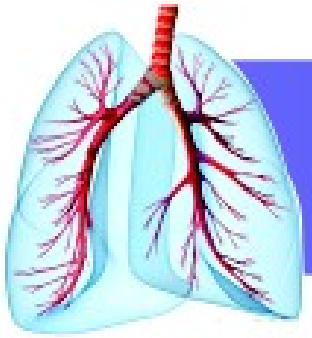
ECMO IN SEPSIS

1990

Extracorporeal Membrane Oxygenation Therapy in Neonates With Septic Shock

Susan McCune, Billie Lou Short, Marilea K. Miller, Andrea Lotze, and Kathryn D. Anderson. Journal of Pediatric Surgery, Vol.25, No.5(May), 1990:pp479-482

- Because of risks of hemorrhage and history of poor survival, a number of institutions do not consider septic neonates for ECMO therapy
- 10 Patients with shock ⟶ All survived
- ECMO is viable alternative for neonates with septic shock



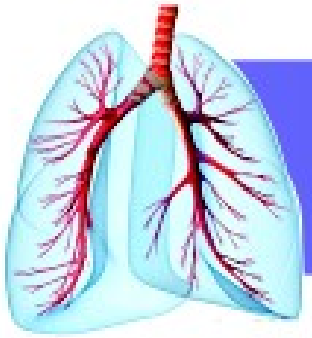
ECMO IN SEPSIS

1994

Extracorporeal Membrane Oxygenation for Refractory Septic Shock in Children

John Beca and Warwick Butt. Pediatrics, Vol. 93, No. 5, May 1994: pp. 726-729

- 9 children with sepsis ⟶ 5 survived (All VA ECMO)
- Septic shock should not be contraindication to ECMO
- ECMO can support the circulation in children with refractory septic shock



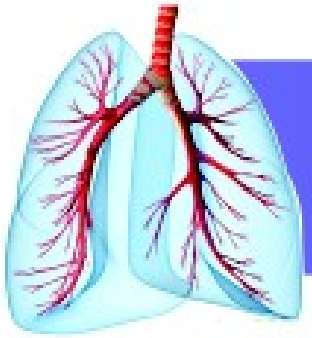
ECMO IN SEPSIS

2007- Review Article

Extracorporeal Membrane Oxygenation and Sepsis

Graeme MacLaren and Warwick Butt. Critical Care and resuscitation, Volume 9, Number 1, March 2007: pp76-80

- Historically, sepsis considered contraindication to ECMO
- VV cannulation for respiratory failure
- VA cannulation for circulatory failure
- Patients with sepsis can be successfully supported on ECMO

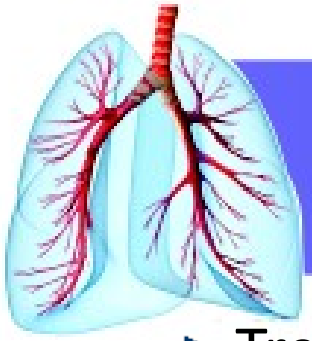


ECMO IN SEPSIS

Extracorporeal Membrane Oxygenation For Refractory Septic Shock in Children: One Institution's Experience.

Graeme MacLaren , Warwick Butt, Derek Best, Susan Donath, Anna Taylor. Pediatr Criti Care Med 2007, Volume 8, Number 57: pp447-451

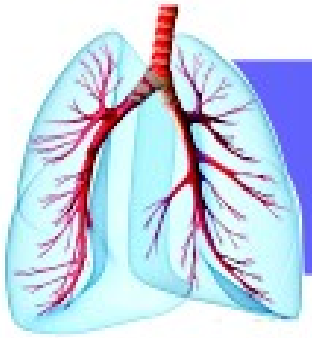
- Reviewed records from 1998-2006
- 441 Children requiring ECMO
- 45 (10%) - Septic shock
- All placed on VA ECMO (central cannulation)
- 21 (47%) - Survived to hospital discharge



EXPERIENCE

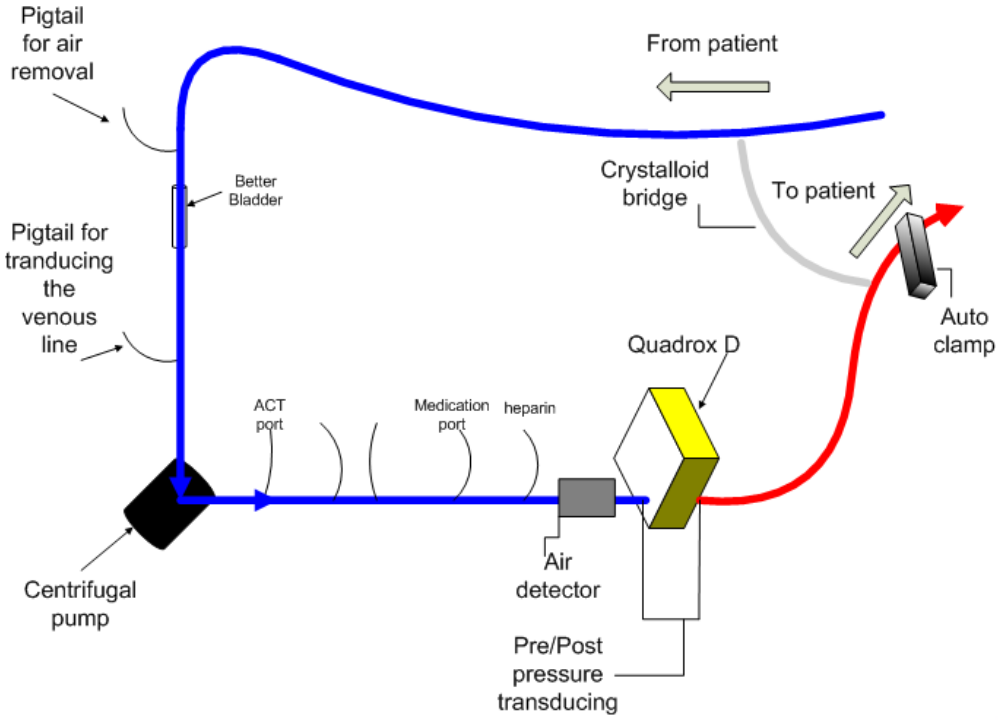
- Treating AT-III earlier, considering prime addition/continuous infusion
- Using Anti Xa for heparin adjustments
- ACT for trending, hourly POC testing
- Constant communication

FLOW	ACT
Flow >2,5l/min	160-180 sec
Flow 2-2,5l/min	180-200 sec
Flow <2 l/min	>250 sec



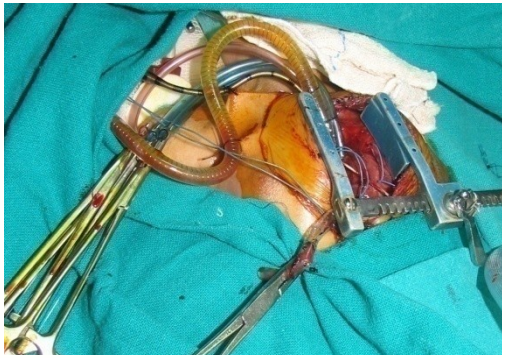
COMPLICATIONS

- Bleeding
- Thrombosis
- Heparin resistance
- Heparin induced thrombocytopenia



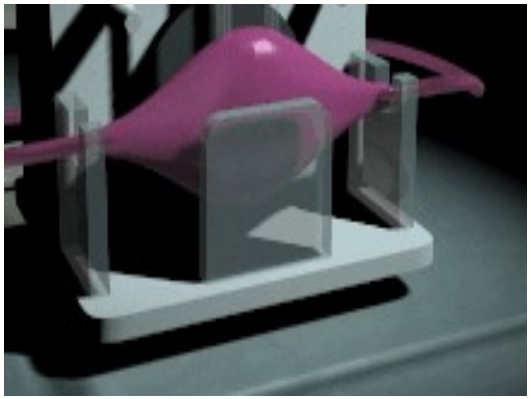
ECMO COMPLICATIONS

Circuit



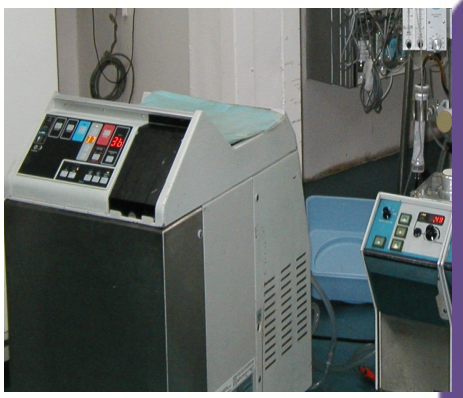
Cannulas

Bleeding

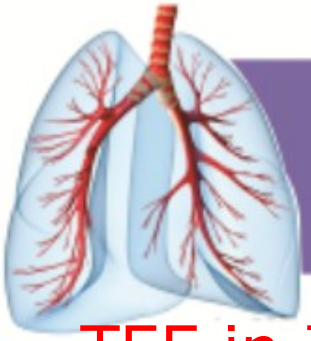


Bladder

Oxygenator

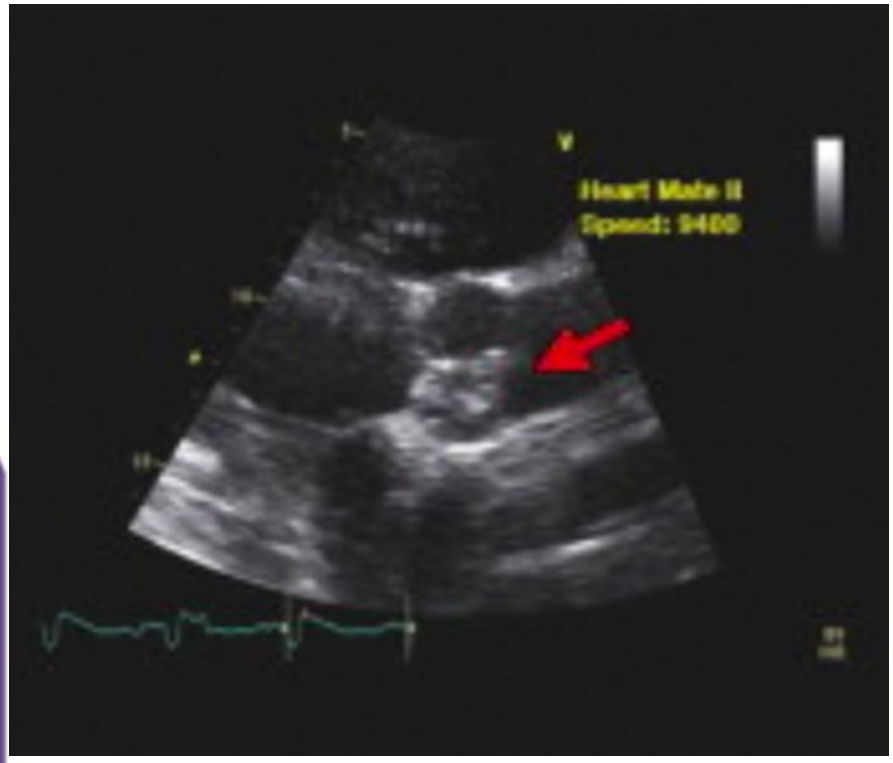


Heat exchanger



ECMO COMPLICATIONS – THROMBOSIS

TEE in ICU good tool to Detect Thrombosis

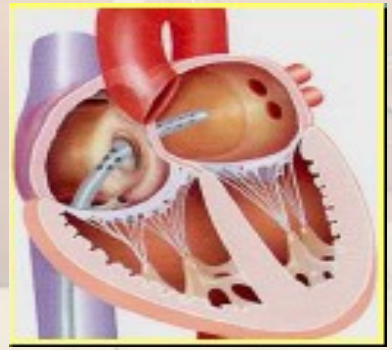


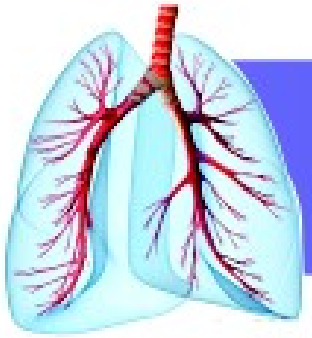
"The Role of Echocardiography and Other Imaging Modalities in Patients With Left Ventricular Assist Devices". Jerry D. *J Am Coll Cardiol Img*. 2010;3(10):1049-1064.

BLEEDING TREATMENT

- **Exploration – suturing/compression**
- **Cryoprecipitate**
  - Factors VIII & XIII, vWF & fibrinogen
  - Used to replace fibrinogen losses
  - IV Dose - 1 to 10 units (1 unit/5 kg)
- **Fresh frozen plasma**
  - Factors II, V, VII, XI, X
  - Used to replace multiple factor deficiencies (DIC)
  - IV dose 10-20 cc/kg
  - Expensive volume expander
- **Fibrin glues**
  - Composed of thrombin, fibrinogen and/or Factor XIII & antifibrinolytics
  - Control local bleeding - works best with concomitant IV therapy
- **Activated Factor VIIa**
  - Binds to activated platelets, Activates Factor X, Aids TF binding
  - 90-120 ug/kg Q 2 hours till bleeding stops

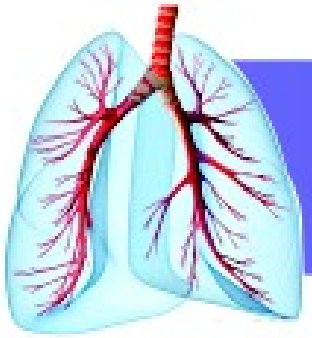
Left atrial drainage cannula 14F
Central ecmo





CONCLUSIONS

- ECMO may be preferred mode in sepsis
- Decreased risk of mortality versus VA ECMO
- Most pronounced in neonatal period
- VV avoids arterial cannulation Utilizes patient plasticity
- Preferred in high output shock, VA may be better in low output shock
- Provides better Pulmonary oxygenation and coronary oxygenation



CONCLUSIONS

Better cerebral auto regulation and decreased intracranial complications

Would like to prospectively look at VV ECMO in septic patients


BY THE WAY, HAS ANYONE SEEN THE PERFUSIONIST?
HEEEEEEELP!!!!

Team Work makes the Dream Work