37th Vicenza Course on AKI & CRRT

May 28-30, 2019

ECMO 101 (and the kidney)

Andrew Shaw FRCPC FRCA FFICM MMHC
Professor and Chair
Department of Anesthesiology and Pain Medicine
University of Alberta

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2019 Disclosures

- Edwards Lifesciences
- FAST Biomedical
- Astellas
- **No off label comments**

What I can't do in 20 minutes..

- Review the entire literature regarding the evidence for ECMO support
- Review different modalities to provide support for organ dysfunction
- *So instead we'll do: ECMO Made Easy*
  - Concepts are easy
  - Details and experience really matter

Goals

- ECMO alphabet soup – what do the letters mean?
- Basics of the circuit
- Cannulation options
- Indications and contraindications
- Managing the patient and pump

What is ECMO ?

- Extra Corporeal Membrane Oxygenation
- Used for cardiac and/or respiratory support
- Very similar to cardiopulmonary bypass (Gibbon 1953), first bedside use 1970s
- Polymethyl pentene (PMP) oxygenator technology has transformed the technique into a survivable procedure
- VA: Veno–Arterial: – support for both lungs and heart
- VV: Veno–Venous: – support for lungs only
- Unlike CPB, ECMO has no blood reservoir

What is ECMO ?

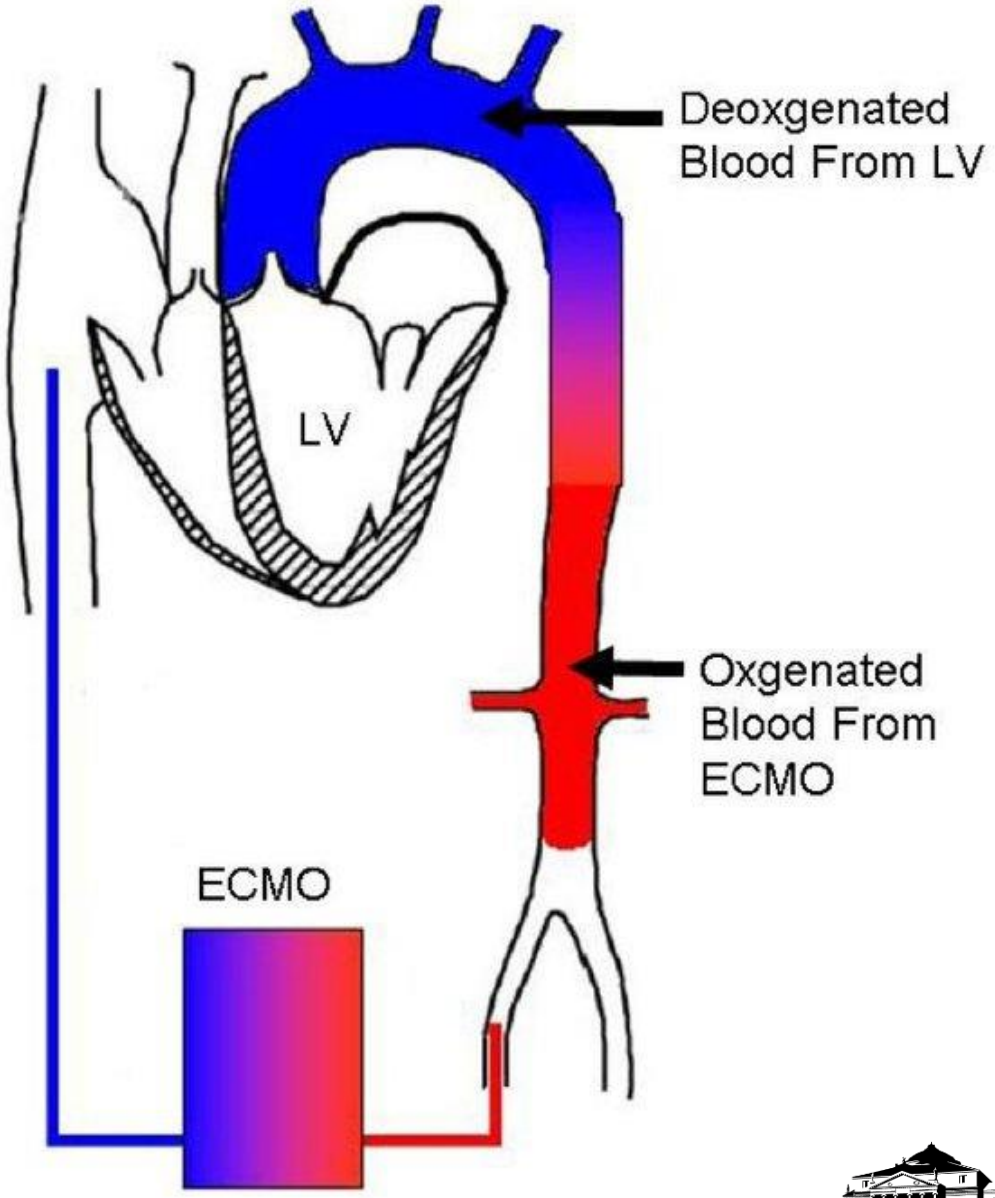
Basic principle:

- **De-saturated blood is drained via (one or more) venous cannulae**
- **CO_2 is removed, O_2 added via an oxygenator**
- **Blood is then returned to systemic circulation via another vein (VV ECMO) or artery (VA ECMO)**

Physiology of ECLS: VA ECMO

- Replaces/augments both pulmonary and cardiac function
- Perfusate mixes in the aorta with blood from left ventricle (arriving from compromised lungs); thus O_2/CO_2 content = content of blood returning from the circuit + that of pulmonary source
  - NB Harlequin syndrome with periph VA ECMO
- Systemic blood flow = ECMO flow + pt's own Cardiac Output

Harlequin Syndrome



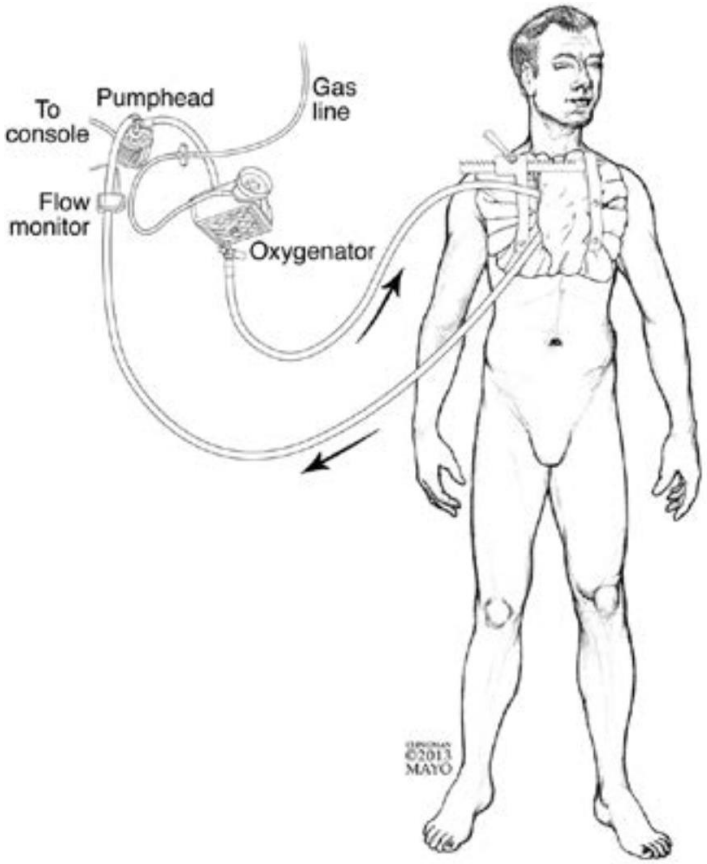
What does it cost?

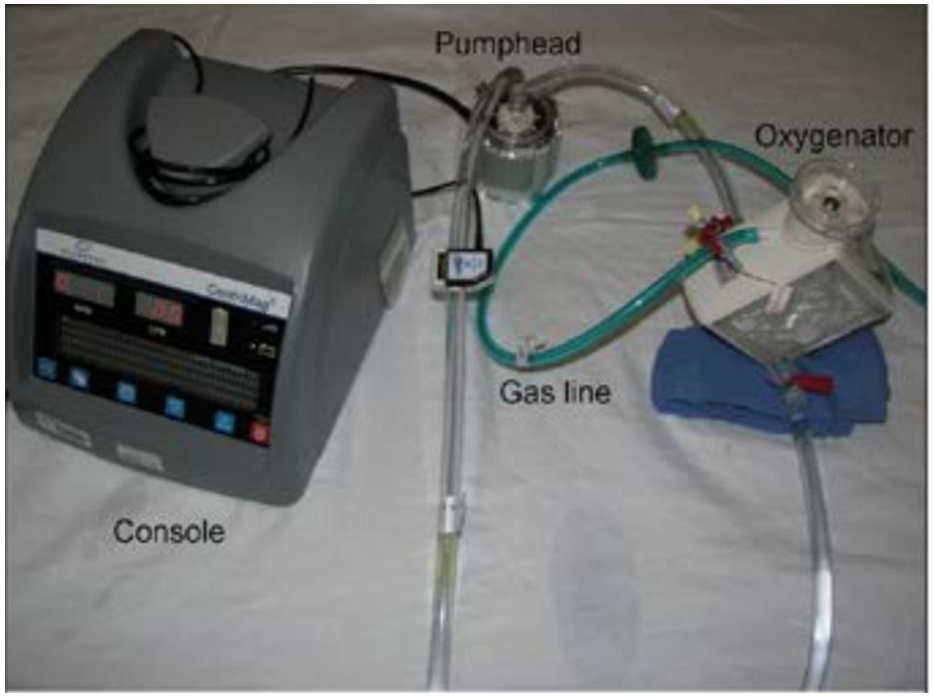
- **ECMO Costs:**
  - **Set up: $2,825,000**
  - **Yearly: $ 2,500,000**
  - **Cost per patient: $90,000 - $120,000**
- **People Costs:**
  - **Physician investment**
  - **Burn out**
  - **Resource utilization**

Physiology of ECLS: VV ECMO

- Replaces/augments pulmonary function only
- Venous blood drains from, and is returned to the right atrium
- Oxygenated blood is thus delivered to the pulmonary artery and lungs – not physiological
- Goal is thus to assist the native lungs, and if necessary to replace them
- Aim to rest native lungs and prevent VILI (baro/volotrauma)
- Systemic blood flow = pt's own Cardiac Output

ECMO Circuitry





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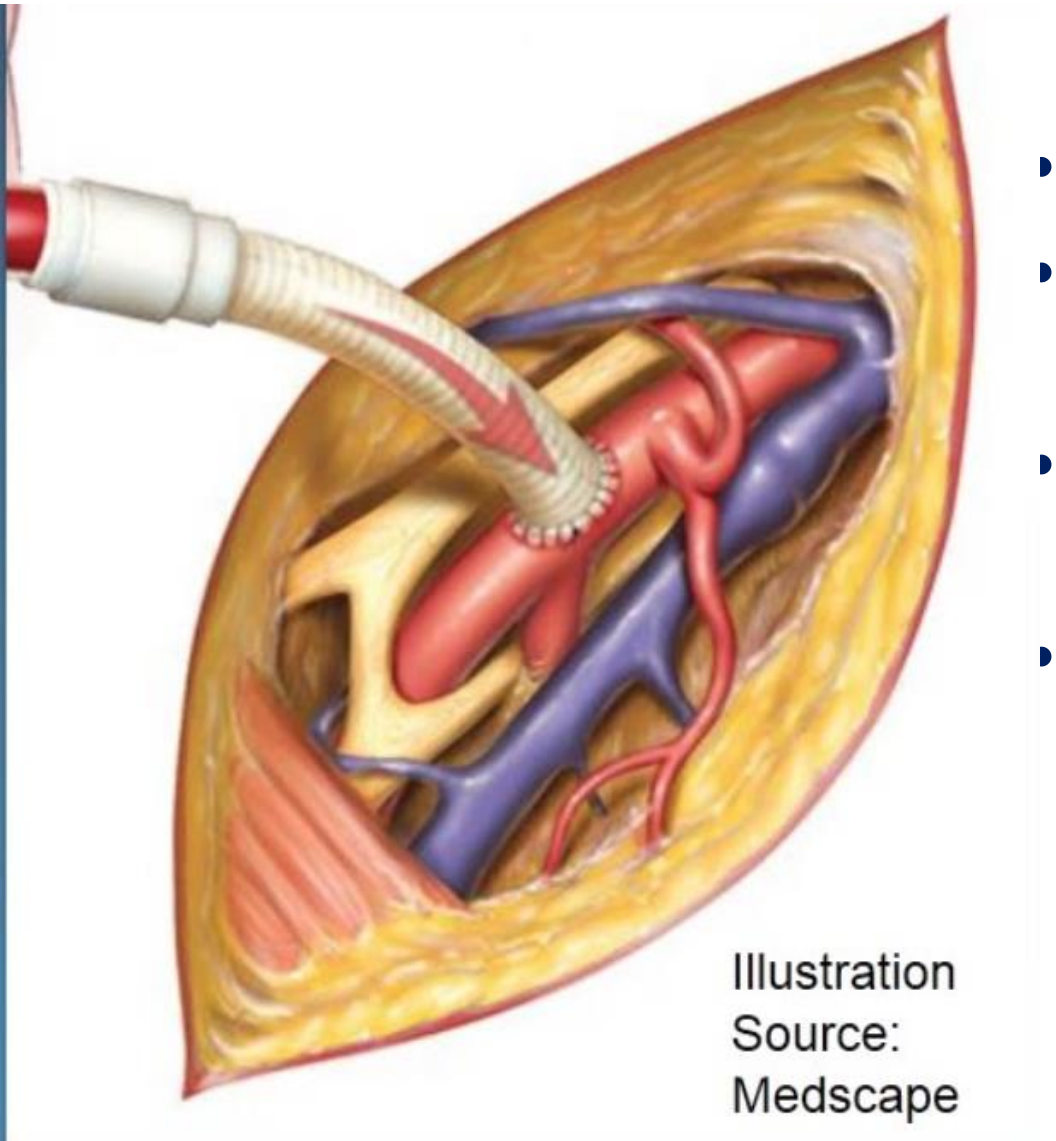
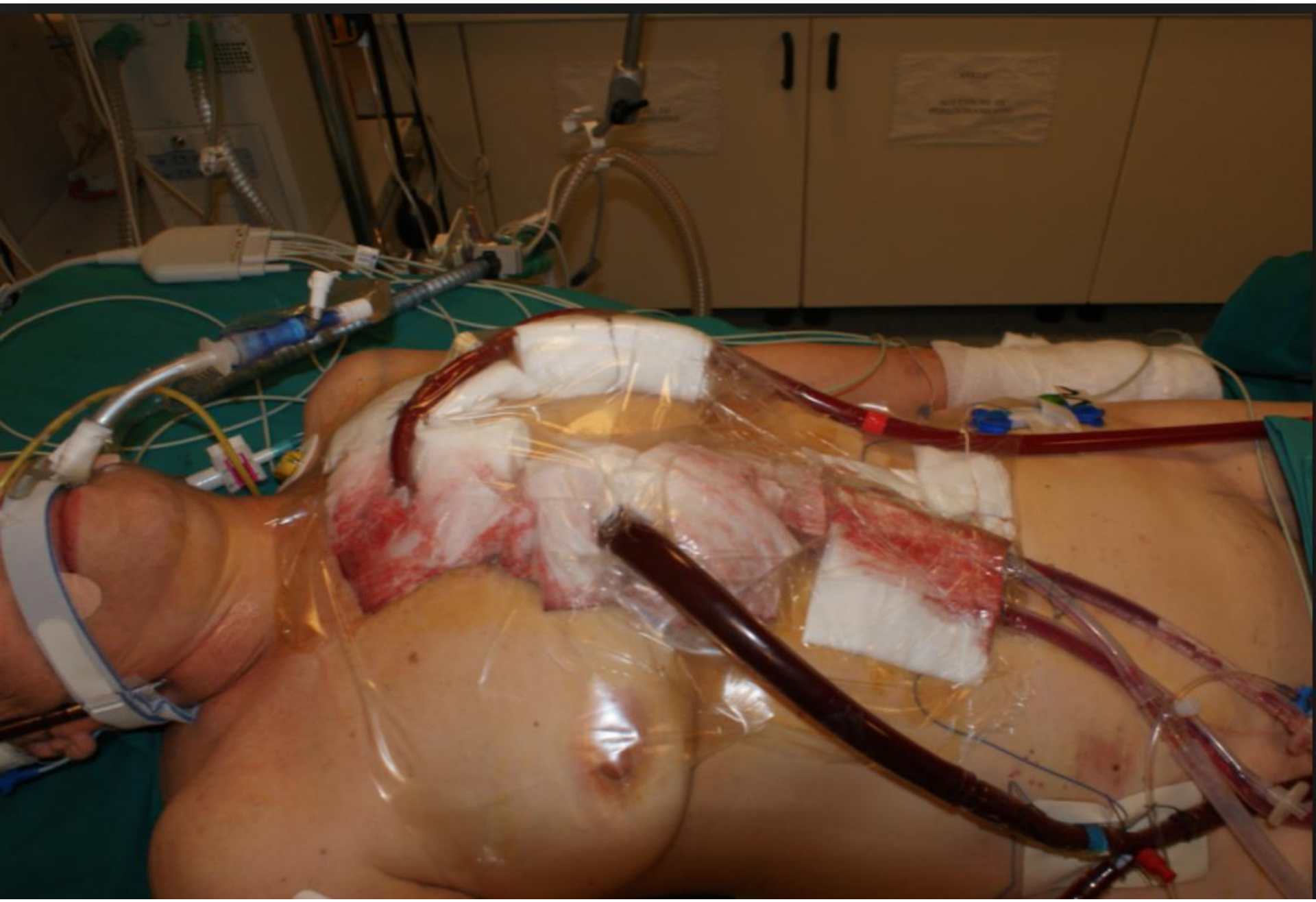
Cannulation

- Requires at least one venous access point
- Another venous return for VV
- Arterial return for VA
- Surgical cut down (usually)
- Traditionally realm of
  - General surgeon
  - CT surgeon

Cannulation



- Femoral cut down
- Central requires sternotomy
- Bleeding can be a big problem
- Required comfort with vascular anatomy and pumps



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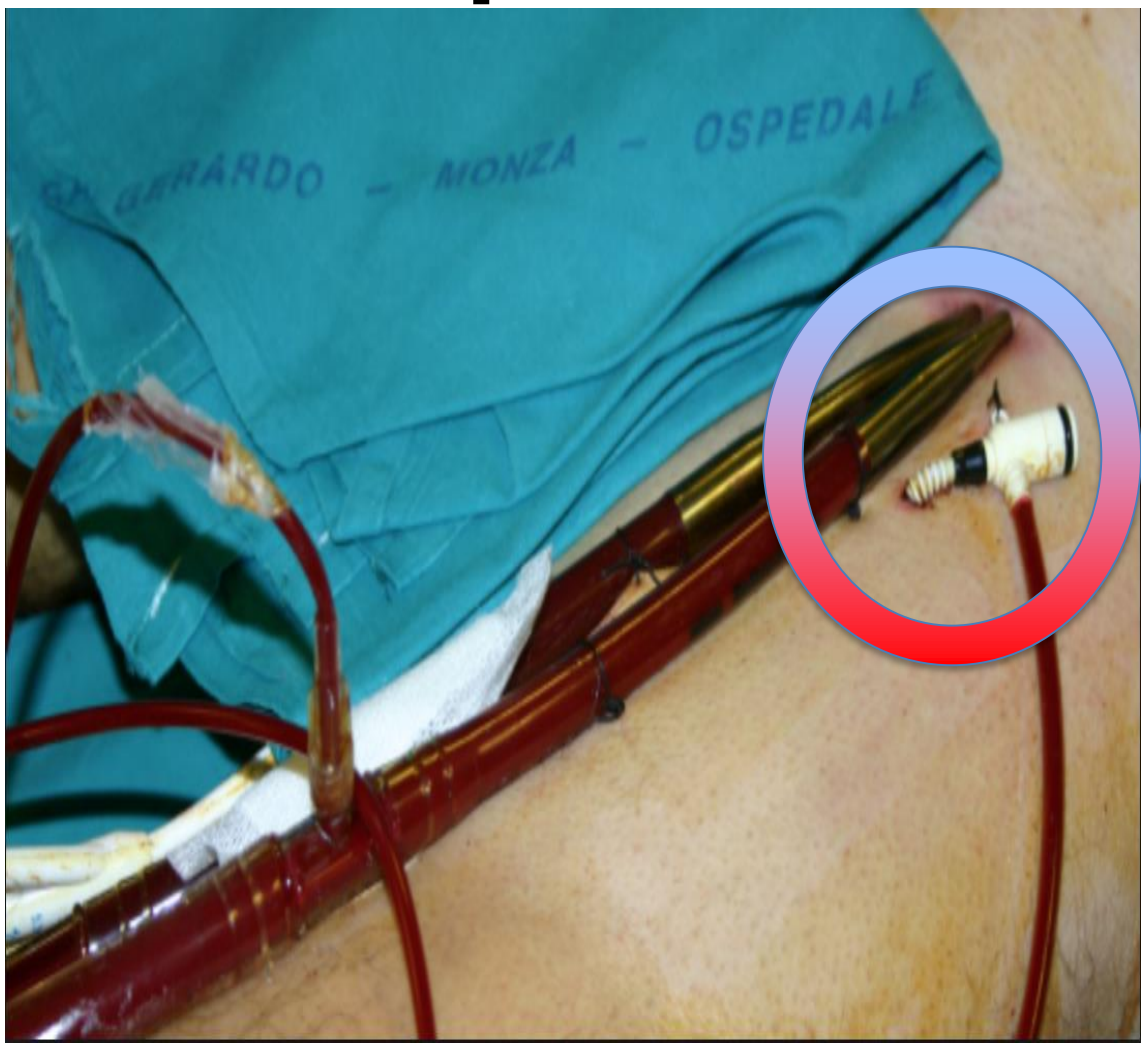
Newer techniques

- Development of percutaneous techniques
- Newer materials
- Larger cannulas
- Pumps and oxygenators



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Cannula options

Femoral arterial cannula for adult
VA or RIJ cannula for VV
(19 or 21 French)

Femoral venous cannula for adult
VA or VV
(23 or 25 French)

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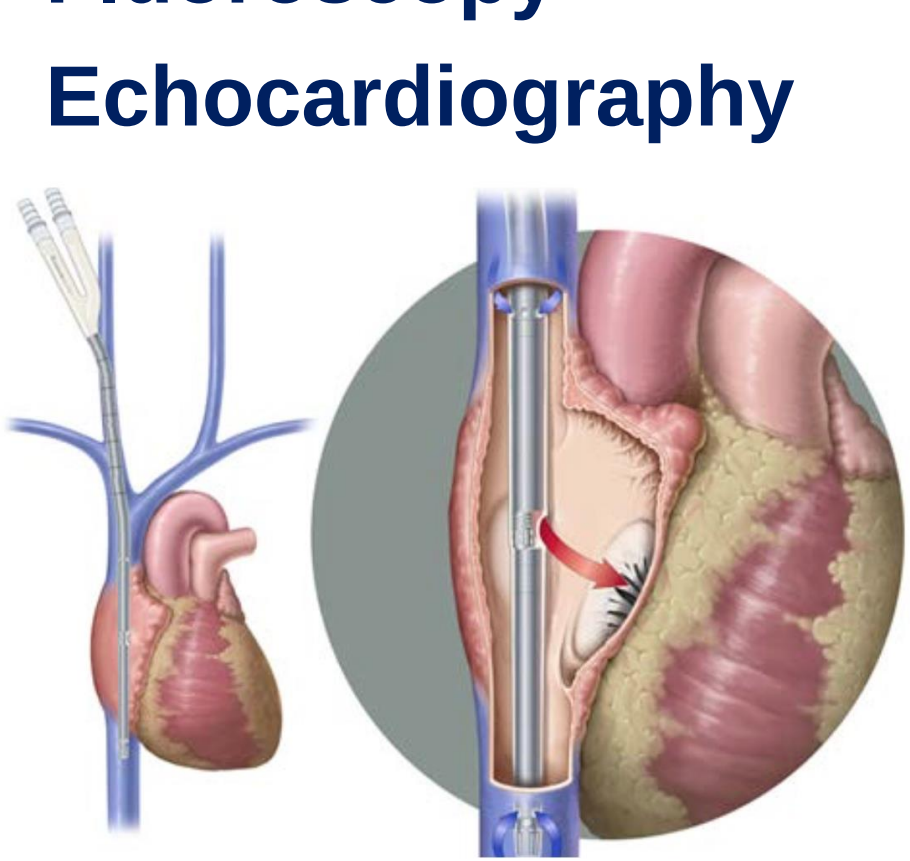
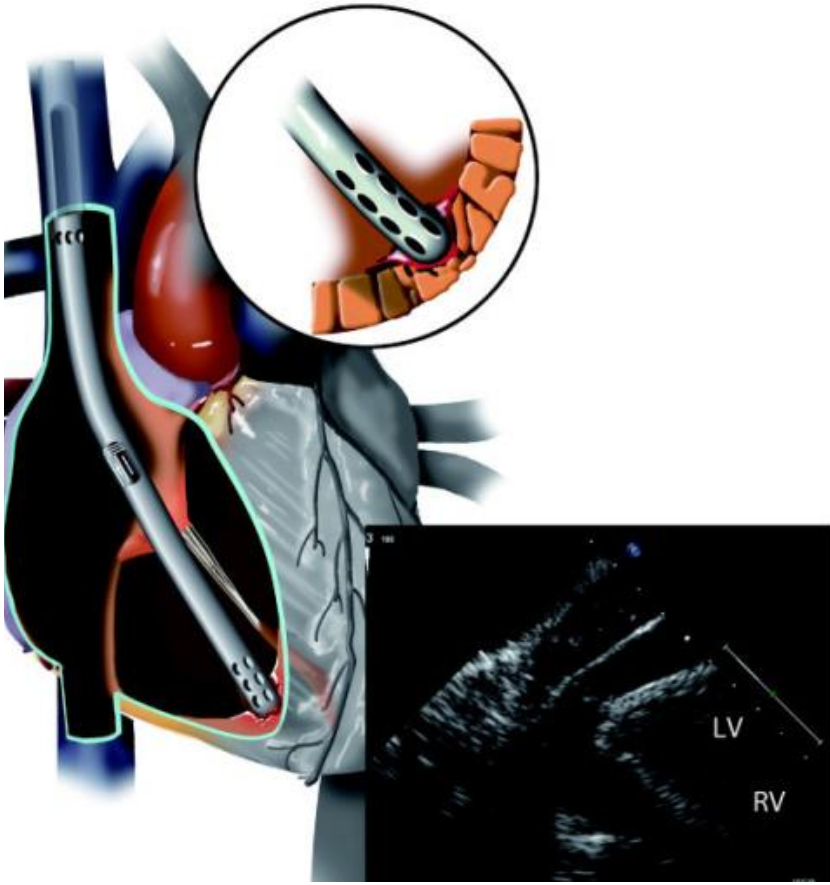
Guidance

- **Fluoroscopy**
- **Echocardiography**





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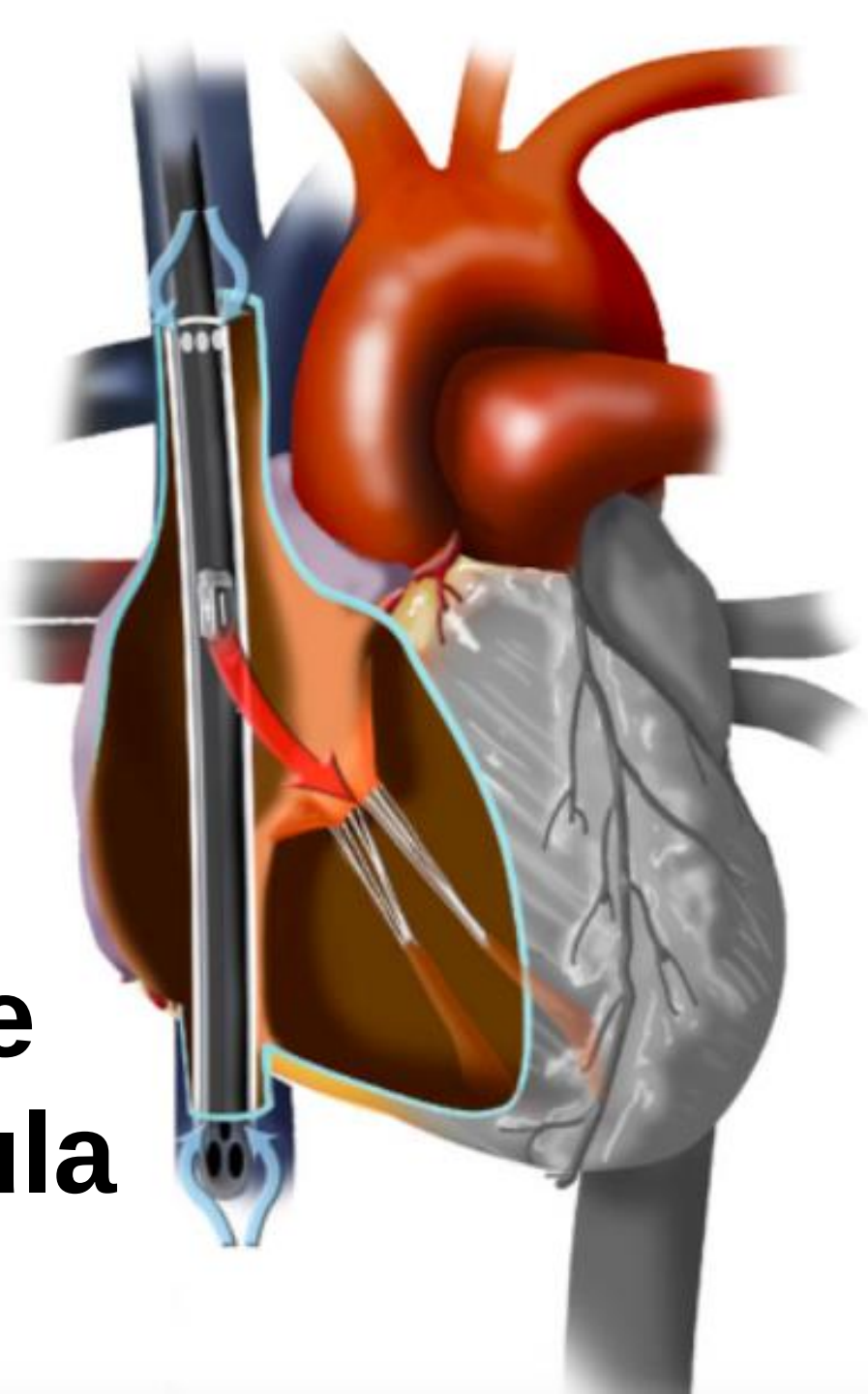

The Avalon Elite VV ECMO Cannula

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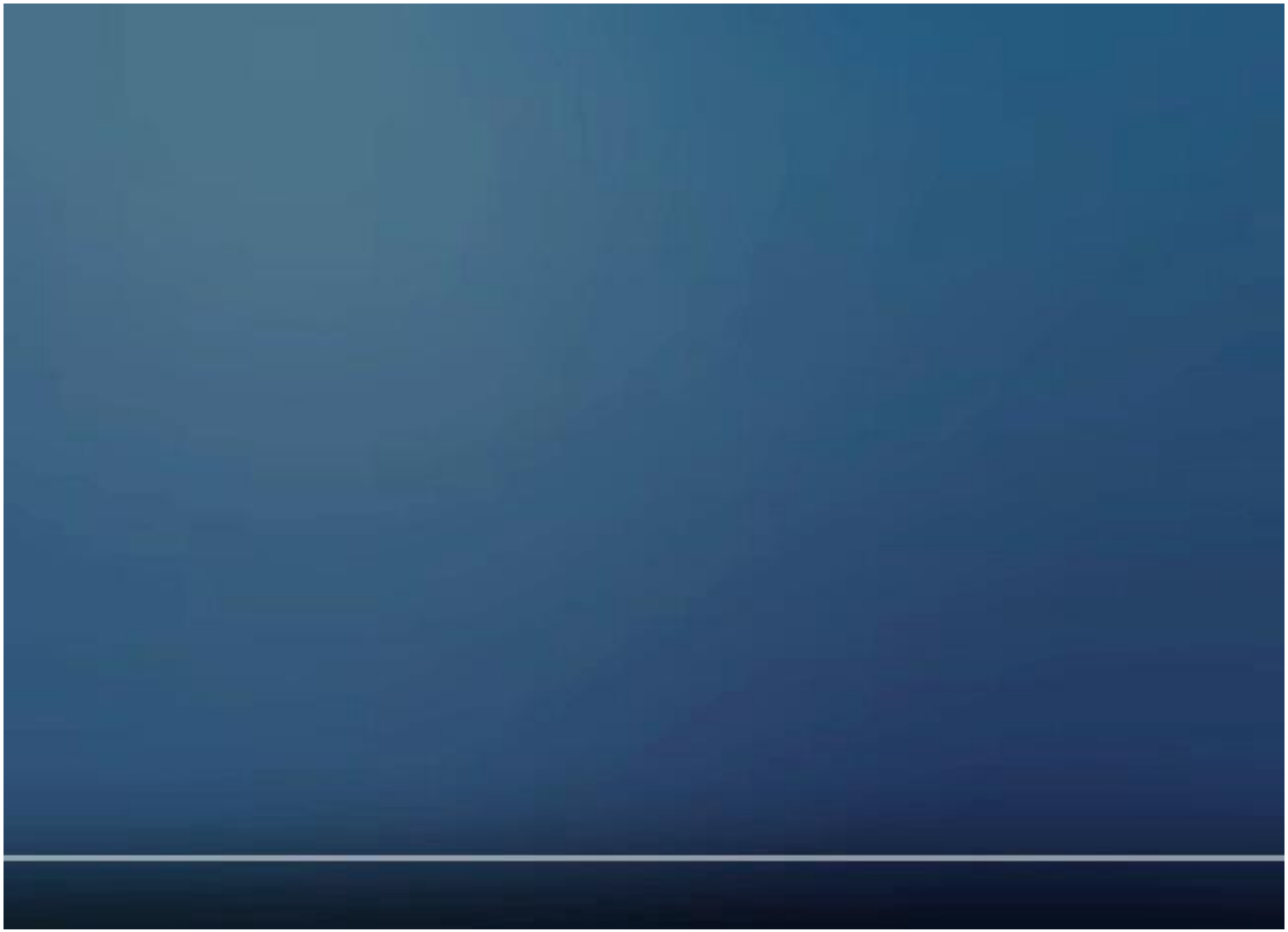
The Avalon Elite VV Cannula



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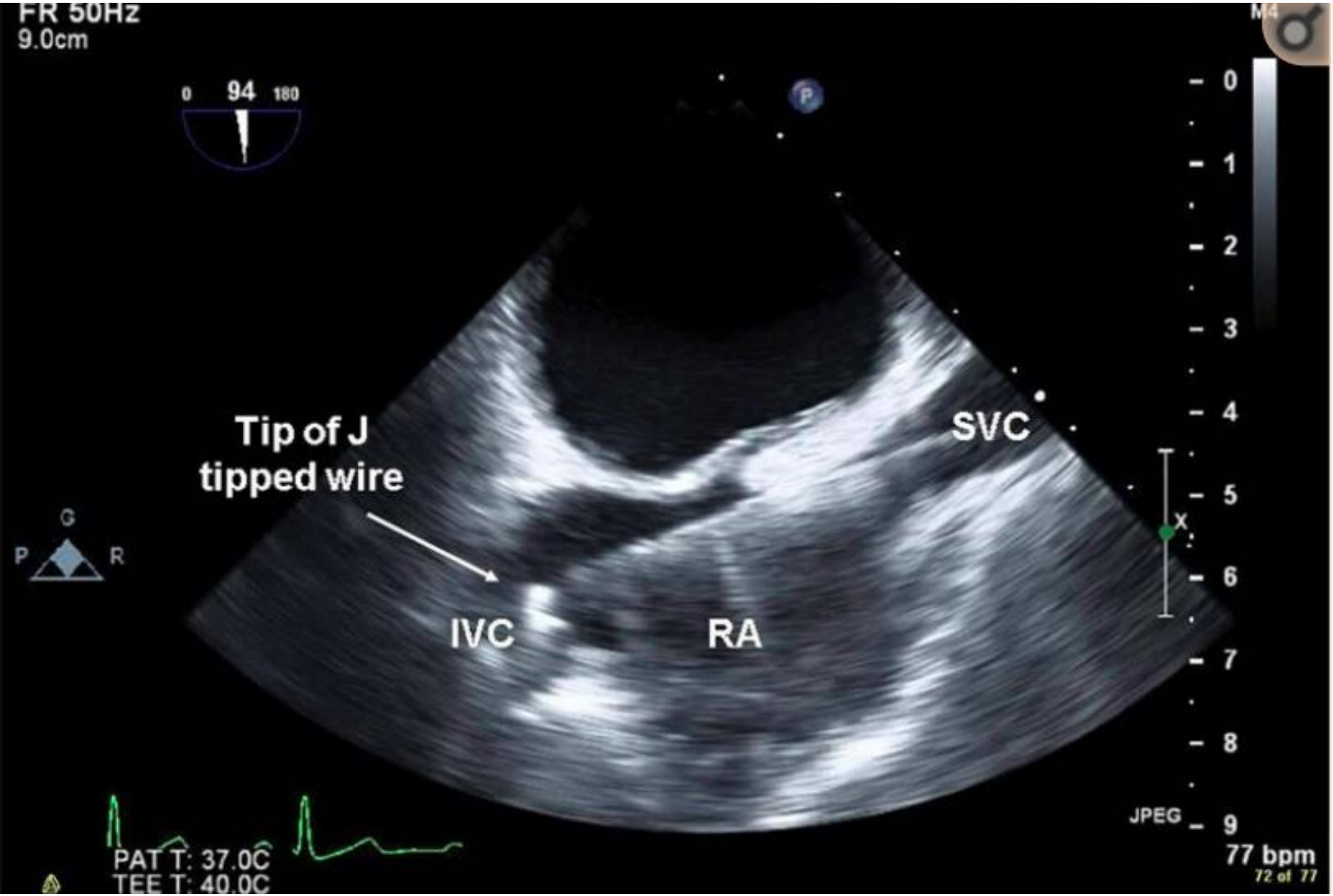

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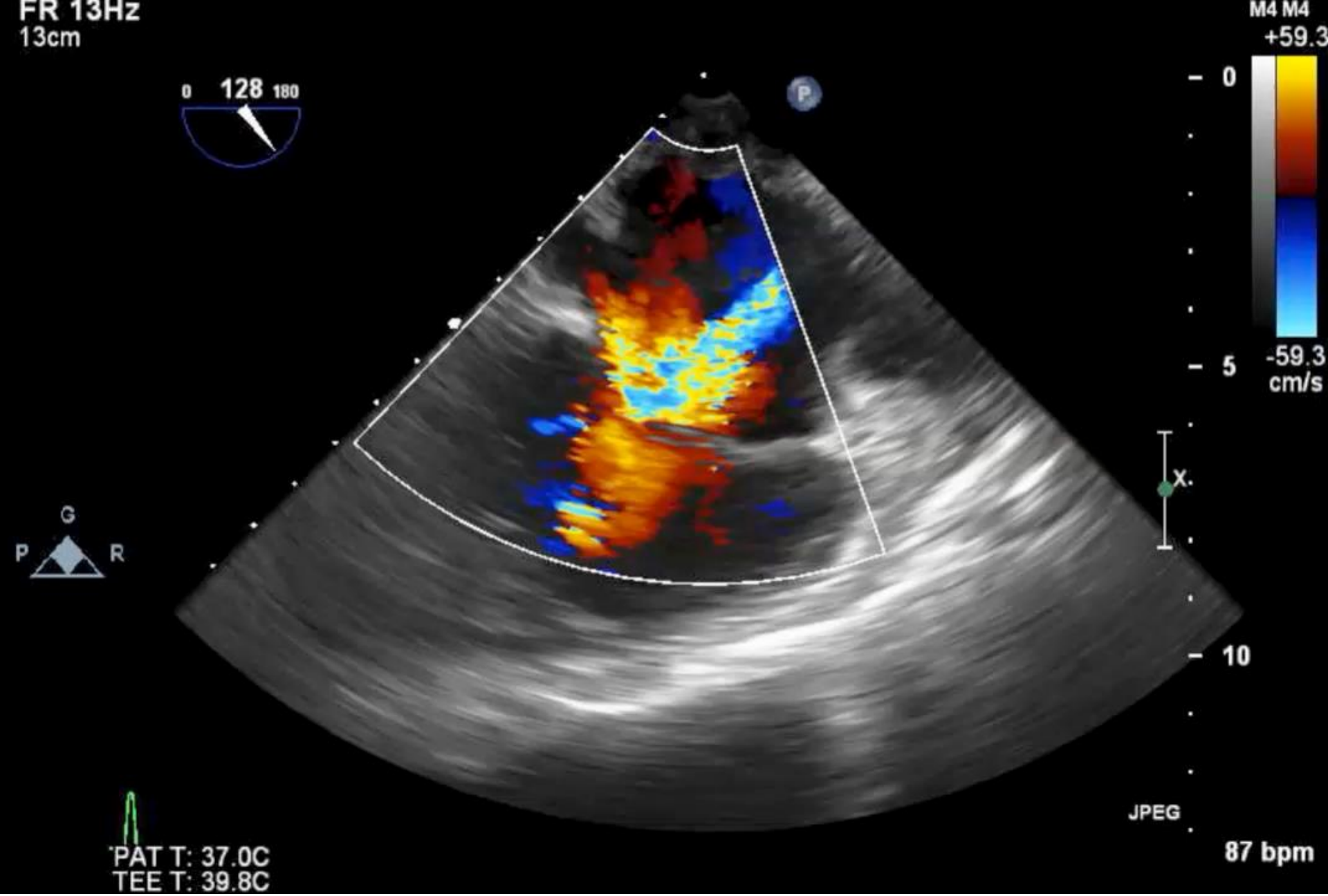

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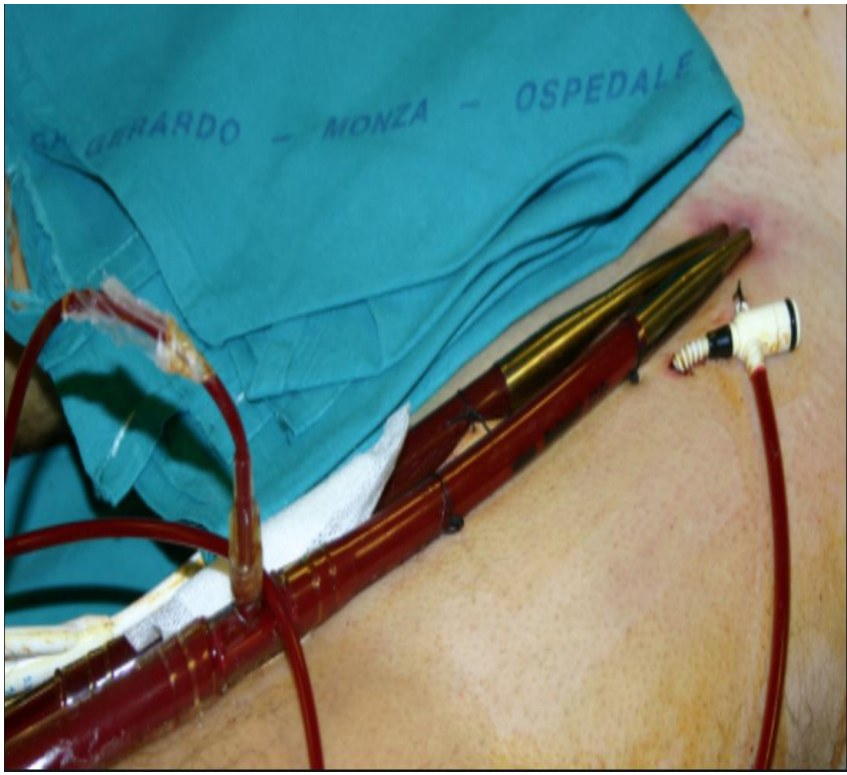
Anticoagulation

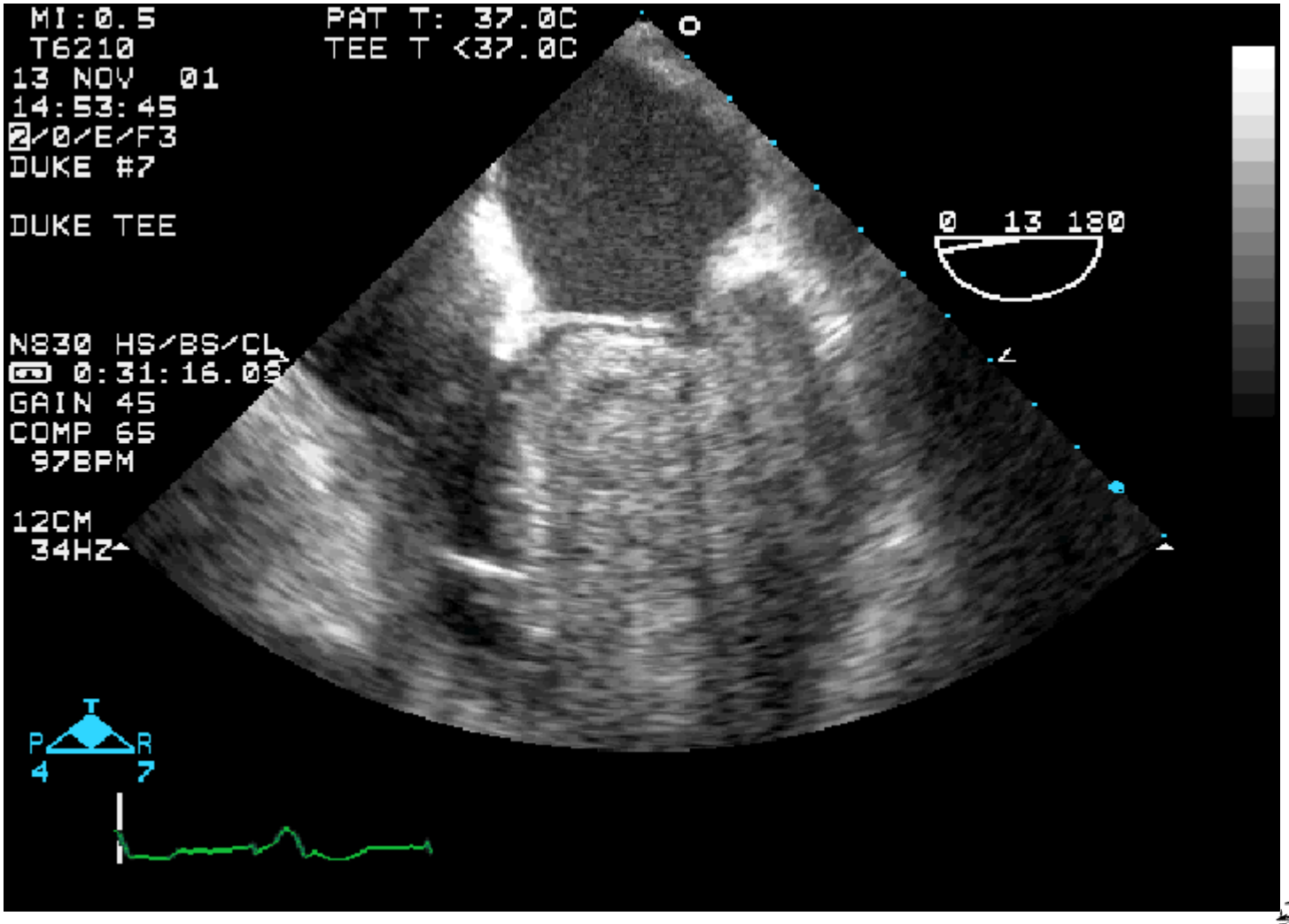
- Heparin most commonly used unless proven HIT (ie both PF4 and SRA positive)
- (Bivalirudin and argatroban are very difficult to use for ECMO)
- Given systemically in the ECMO circuit
- Generally to an ACT of 200 secs or PTT 60-80 secs
- We use anti-Xa levels aiming for 0.35 as goal

Complications

Hemorrhagic	Surgical sites
	Cannulation sites
	Gastrointestinal bleeding
	Intracranial bleeding
	Intravascular line sites
Mechanical	Equipment failure (oxygenator, pump, etc.)
	Malpositioned cannulas
	Vessel injury
	Distal limb ischemia
Infectious	Ventilator-associated pneumonia
	Central line–associated blood stream infections
	Catheter-associated urinary tract injections
Systemic	Renal failure
	Encephalopathy
	Hepatic insufficiency
	Myopathy of critical illness
	Multi-organ system dysfunction



The Ultimate Complication



Candidates for ECMO

- **ECMO is appropriate as a support mechanism in patients with REVERSIBLE conditions**

- **It does not treat the underlying condition, and is therefore acceptable only if the underlying pathology is REVERSIBLE**

Cardiac Indications

- Failure to wean from CPB
- Cardiogenic shock secondary to dilated cardiomyopathy, myocarditis, and postpartum cardiomyopathy
- Post-myocardial infarction cardiogenic shock
- Acute cardiac transplant allograft rejection
- Bridge-to-heart transplantation or ventricular assist device insertion
- Obstructive shock secondary to pulmonary embolism
- Sepsis-induced myocardial depression
- Acute drug overdoses
- Support during high-risk heart catheterization procedures
- Persistent malignant arrhythmias

Respiratory Indications

1. severe hypoxemia (PaO_2:FiO_2 ratio <80)
2. severe hypercarbia with acidemia (pH<7.2)
3. Excessively high inspiratory plateau pressures (>35 cm H2O)

When the underlying disease is reversible

Contraindications

Absolute Contraindications	Relative Contraindications
Unrecoverable heart function and not a candidate for heart transplantation or ventricular assist device insertion	Conditions that preclude anticoagulation (eg, intracranial hemorrhage, embolic stroke, preexisting coagulopathy)
Unrecoverable lung function and not a candidate for lung transplantation	Concomitant multiple organ system dysfunction (eg, renal, hepatic, neurologic)
Prolonged CPR with severe neurologic injury	Patient refusal for blood transfusion
Terminal illness such as metastatic cancer	Limited vascular access
	Morbid obesity
	Advanced age
	Poor prior functional status

Volume drives outcome

Am J Respir Crit Care Med. First published online 19 Feb 2015 as DOI: 10.1164/rccm.201409-1634OC

Association of Hospital-Level Volume of Extracorporeal Membrane Oxygenation Cases and Mortality – Analysis of the Extracorporeal Life Support Organization Registry

Ryan P Barbaro , Folafoluwa O Odetola , Kelley M Kidwell , Matthew L Paden , Robert H Bartlett , Matthew M Davis , and Gail M Annich

- **About 30 cases/year improved outcomes**
- **Decreased complications and costs**
- **Improved utilization**

Outcomes

	Total	Survived ECMO	Survive to Discharge
Respiratory	4382	2800 (64%)	2439 (56%)
Cardiac	3401	1877 (55%)	1349 (40%)
ECPR	969	358 (37%)	267 (28%)

Data from ELSO ECMO registry (2013)

ECMO Team

- **Intensivist lead team**
  - **Heart failure Cardiologist for VA ECMO patients**
  - **Heart Failure Surgeon for VA ECMO patients**
  - **Heart failure VAD selection team**
  - **Other relevant personnel**
    - **Physical therapy**
    - **Hematologist**
    - **Respiratory therapist**
    - **Nursing**

Chen *et al. Critical Care* 2014, **18**:675
http://ccforum.com/content/18/6/675

CRITICAL CARE

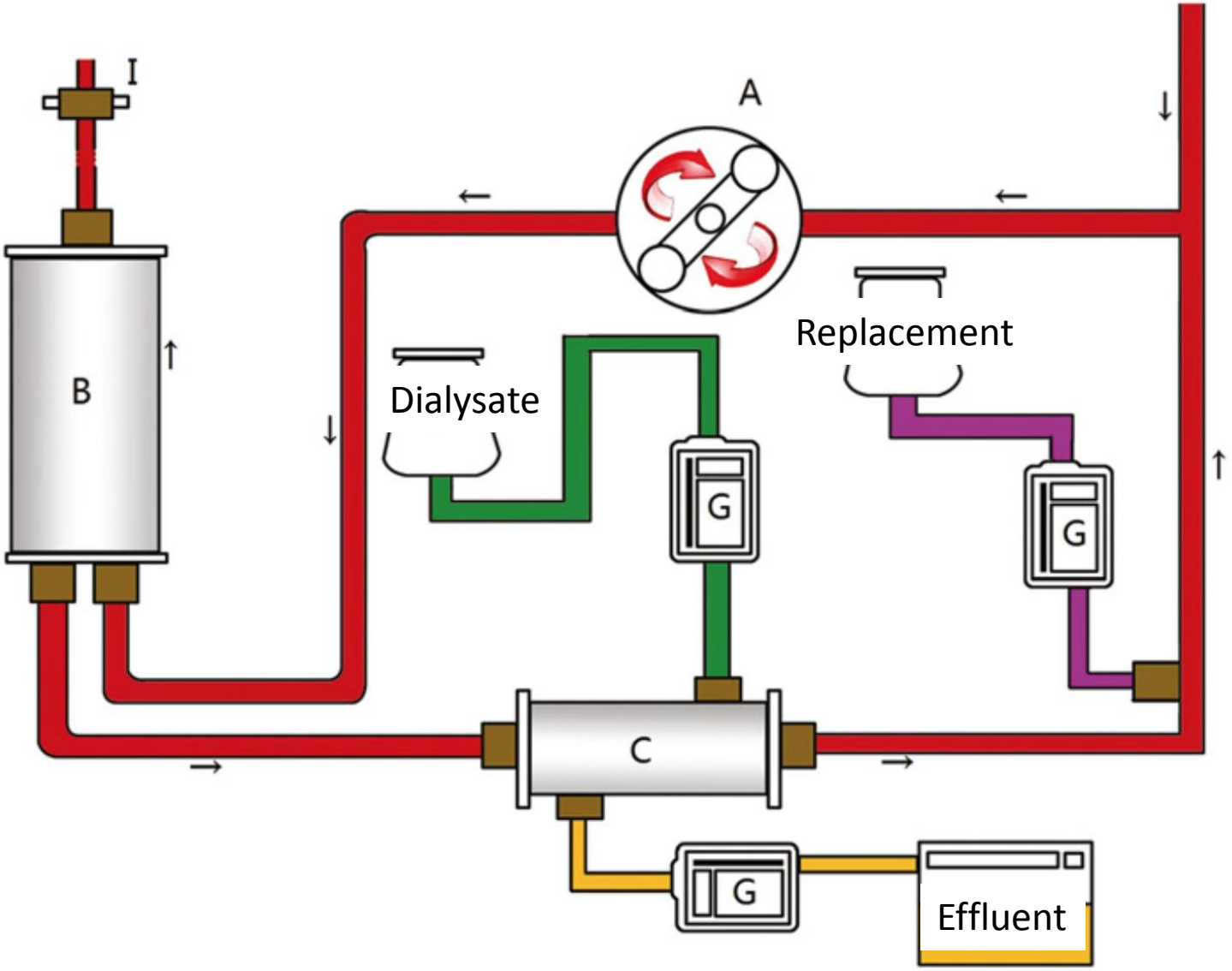
RESEARCH Open Access

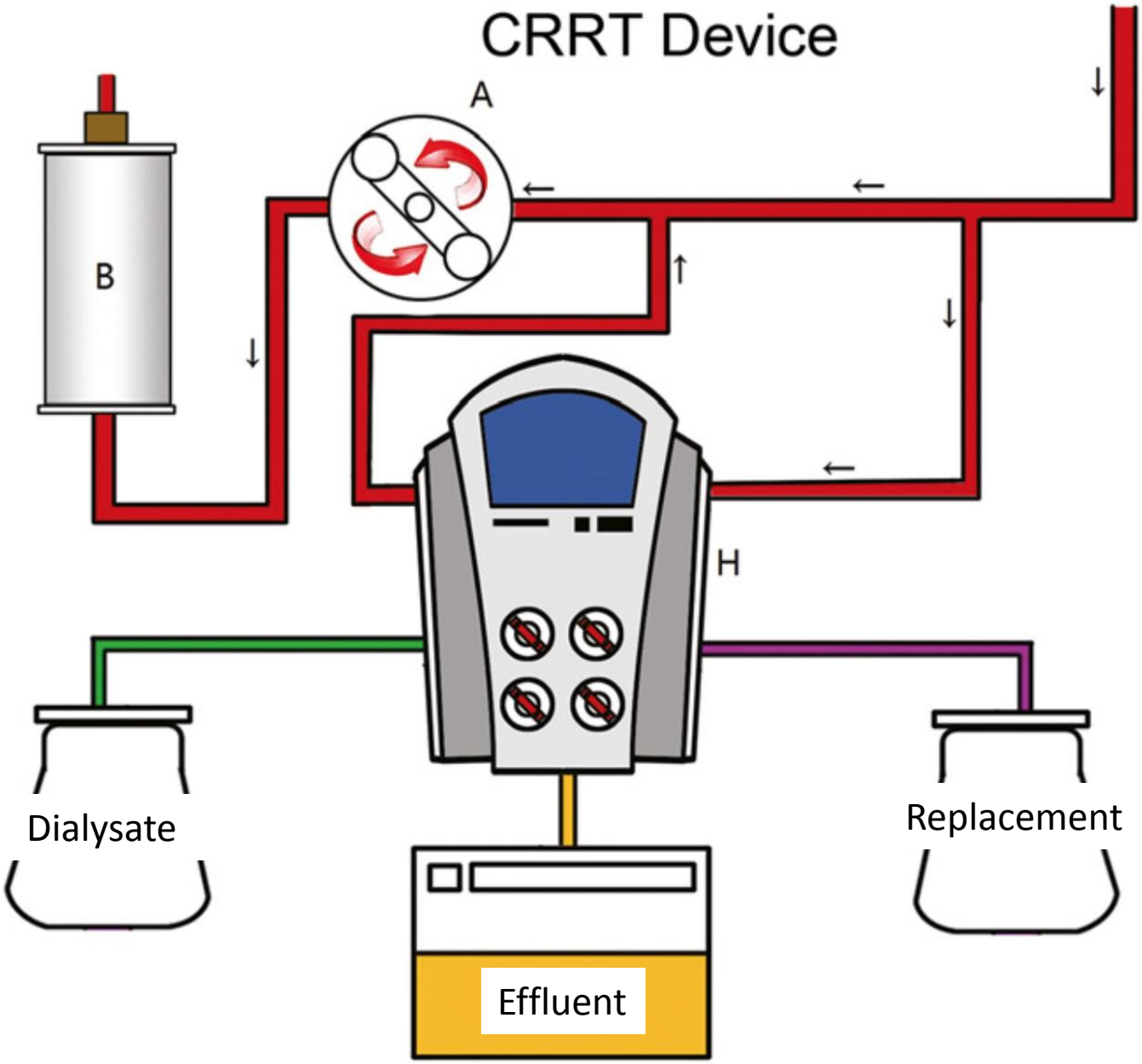
Combination of extracorporeal membrane oxygenation and continuous renal replacement therapy in critically ill patients: a systematic review

Han Chen[1], Rong-Guo Yu[2], Ning-Ning Yin[1] and Jian-Xin Zhou[1*]

- **Separate access**
- **In line (hemofilter included in ECMO circuit)**
- **CRRT circuit dovetailed with ECMO circuit**

In-line Hemofilter

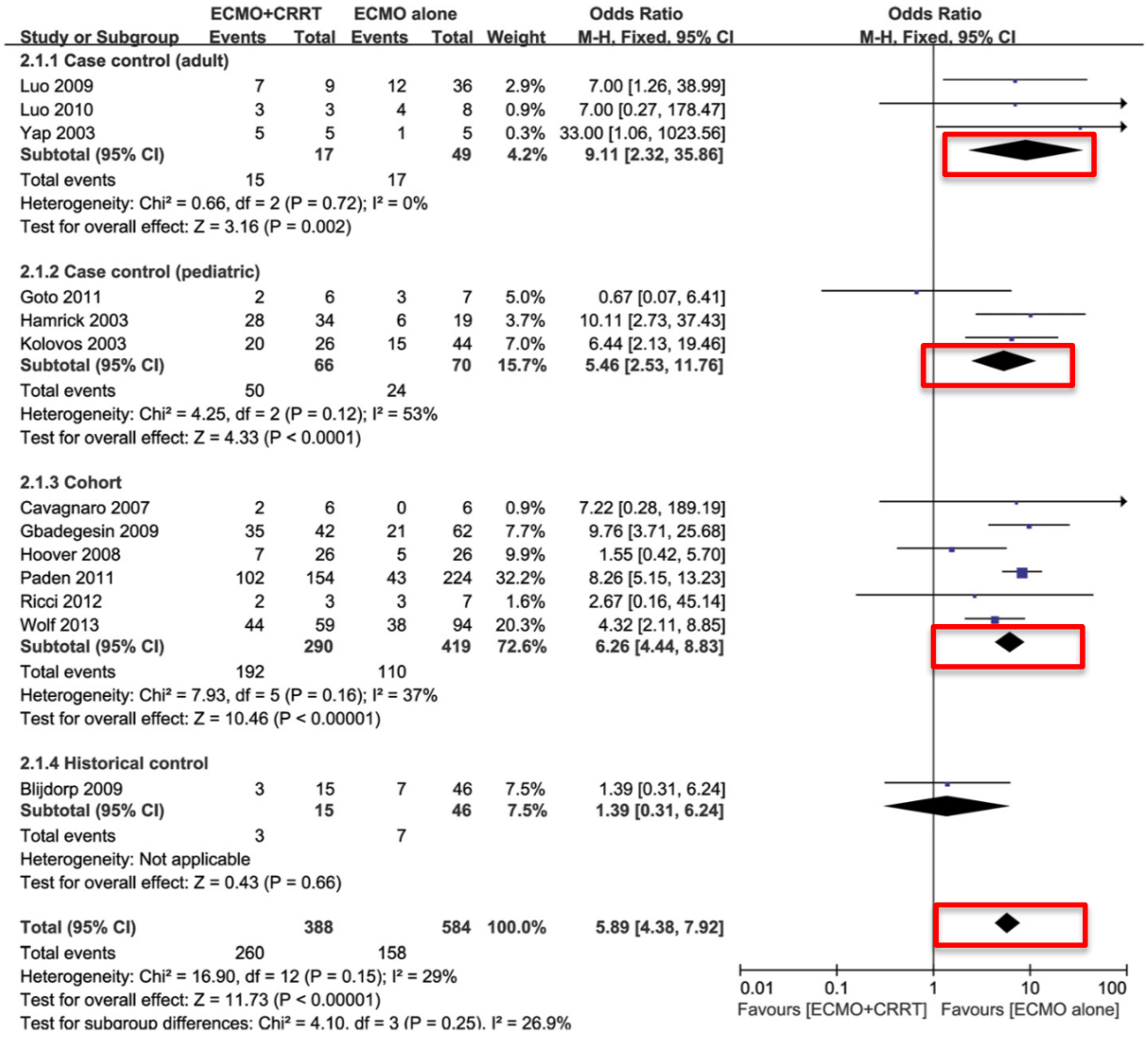



CRRT Device
A
B
H
Dialysate
Replacement
Effluent

ECMO CRRT options

	In Line Hemofilter	CRRT machine
Ultrafiltration control	IV pump controlled	CRRT machine controlled
Metabolic Control	NOT if only using SCUF	YES
ECMO Flow	Blood Shunt decrease ECMO flow decreased PaO2	NO systemic changes
Complexity	Less People	More People

ECMO is better if you can avoid CRRT



Study or Subgroup	ECMO+CRRT Events	Total	ECMO alone Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
2.1.1 Case control (adult)						
Luo 2009	7	9	12	36	2.9%	7.00 [1.26, 38.99]
Luo 2010	3	3	4	8	0.9%	7.00 [0.27, 178.47]
Yap 2003	5	5	1	5	0.3%	33.00 [1.06, 1023.56]
Subtotal (95% CI)		**17**		**49**	**4.2%**	**9.11 [2.32, 35.86]**
Total events	15		17			
Heterogeneity: Chi² = 0.66, df = 2 (P = 0.72); I² = 0%						
Test for overall effect: Z = 3.16 (P = 0.002)						
2.1.2 Case control (pediatric)						
Goto 2011	2	6	3	7	5.0%	0.67 [0.07, 6.41]
Hamrick 2003	28	34	6	19	3.7%	10.11 [2.73, 37.43]
Kolovos 2003	20	26	15	44	7.0%	6.44 [2.13, 19.46]
Subtotal (95% CI)		**66**		**70**	**15.7%**	**5.46 [2.53, 11.76]**
Total events	50		24			
Heterogeneity: Chi² = 4.25, df = 2 (P = 0.12); I² = 53%						
Test for overall effect: Z = 4.33 (P < 0.0001)						
2.1.3 Cohort						
Cavagnaro 2007	2	6	0	6	0.9%	7.22 [0.28, 189.19]
Gbadegesin 2009	35	42	21	62	7.7%	9.76 [3.71, 25.68]
Hoover 2008	7	26	5	26	9.9%	1.55 [0.42, 5.70]
Paden 2011	102	154	43	224	32.2%	8.26 [5.15, 13.23]
Ricci 2012	2	3	3	7	1.6%	2.67 [0.16, 45.14]
Wolf 2013	44	59	38	94	20.3%	4.32 [2.11, 8.85]
Subtotal (95% CI)		**290**		**419**	**72.6%**	**6.26 [4.44, 8.83]**
Total events	192		110			
Heterogeneity: Chi² = 7.93, df = 5 (P = 0.16); I² = 37%						
Test for overall effect: Z = 10.46 (P < 0.00001)						
2.1.4 Historical control						
Blijdorp 2009	3	15	7	46	7.5%	1.39 [0.31, 6.24]
Subtotal (95% CI)		**15**		**46**	**7.5%**	**1.39 [0.31, 6.24]**
Total events	3		7			
Heterogeneity: Not applicable						
Test for overall effect: Z = 0.43 (P = 0.66)						
Total (95% CI)		**388**		**584**	**100.0%**	**5.89 [4.38, 7.92]**
Total events	260		158			
Heterogeneity: Chi² = 16.90, df = 12 (P = 0.15); I² = 29%						
Test for overall effect: Z = 11.73 (P < 0.00001)						
Test for subgroup differences: Chi² = 4.10, df = 3 (P = 0.25), I² = 26.9%						

Conclusions

- **ECMO is a viable option for adults and children**
  - **With REVERSIBLE severe cardio-pulmonary dysfunction**
  - **It is NOT a pre-mortem treatment to prolong the time until death occurs**
- **Cannulation and anticoagulation strategies are vital parts of the technique**
- **If ECMO patients require CRRT then several options exist, but outcomes are worse then if CRRT can be avoided**

Thank you

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