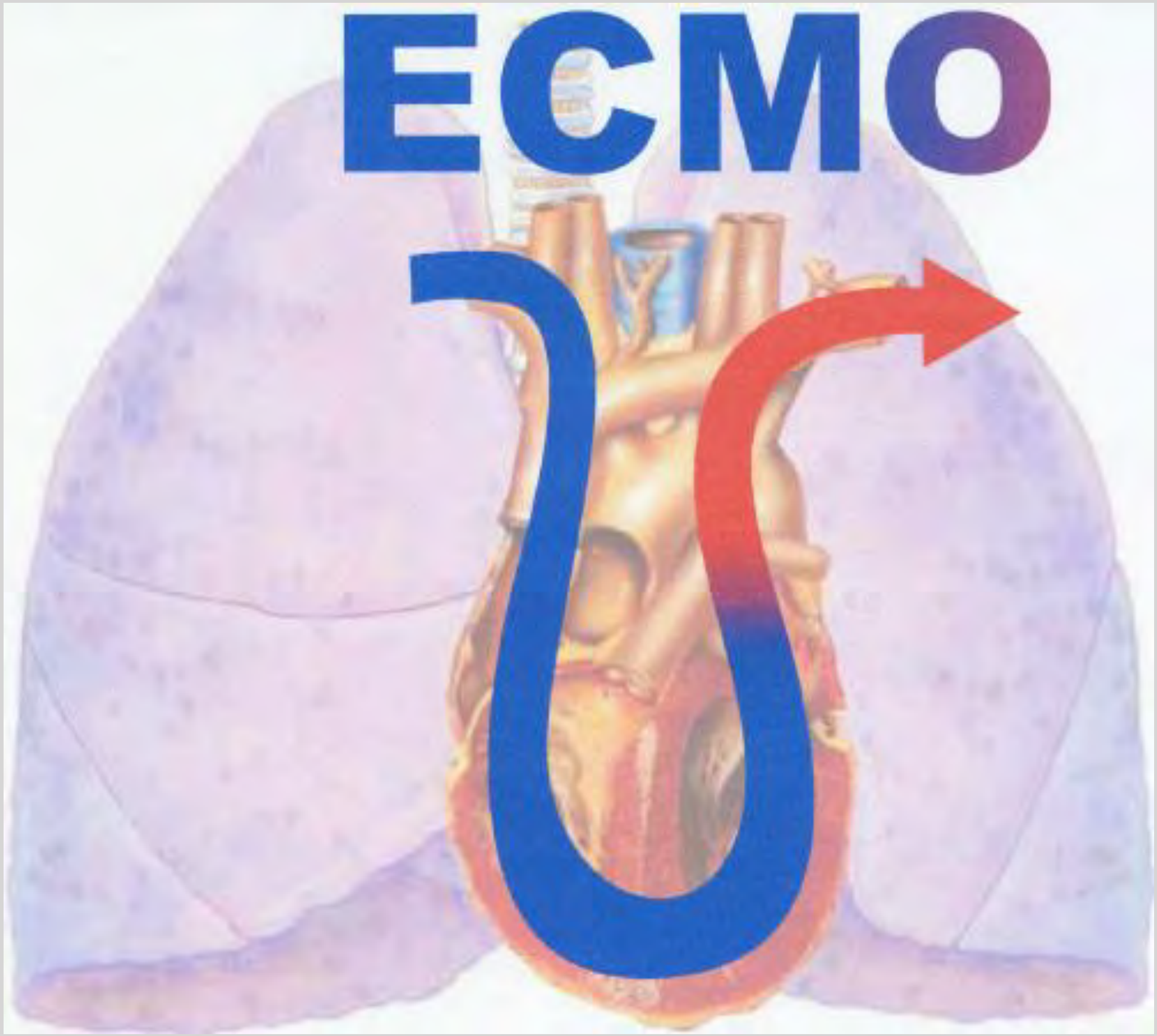
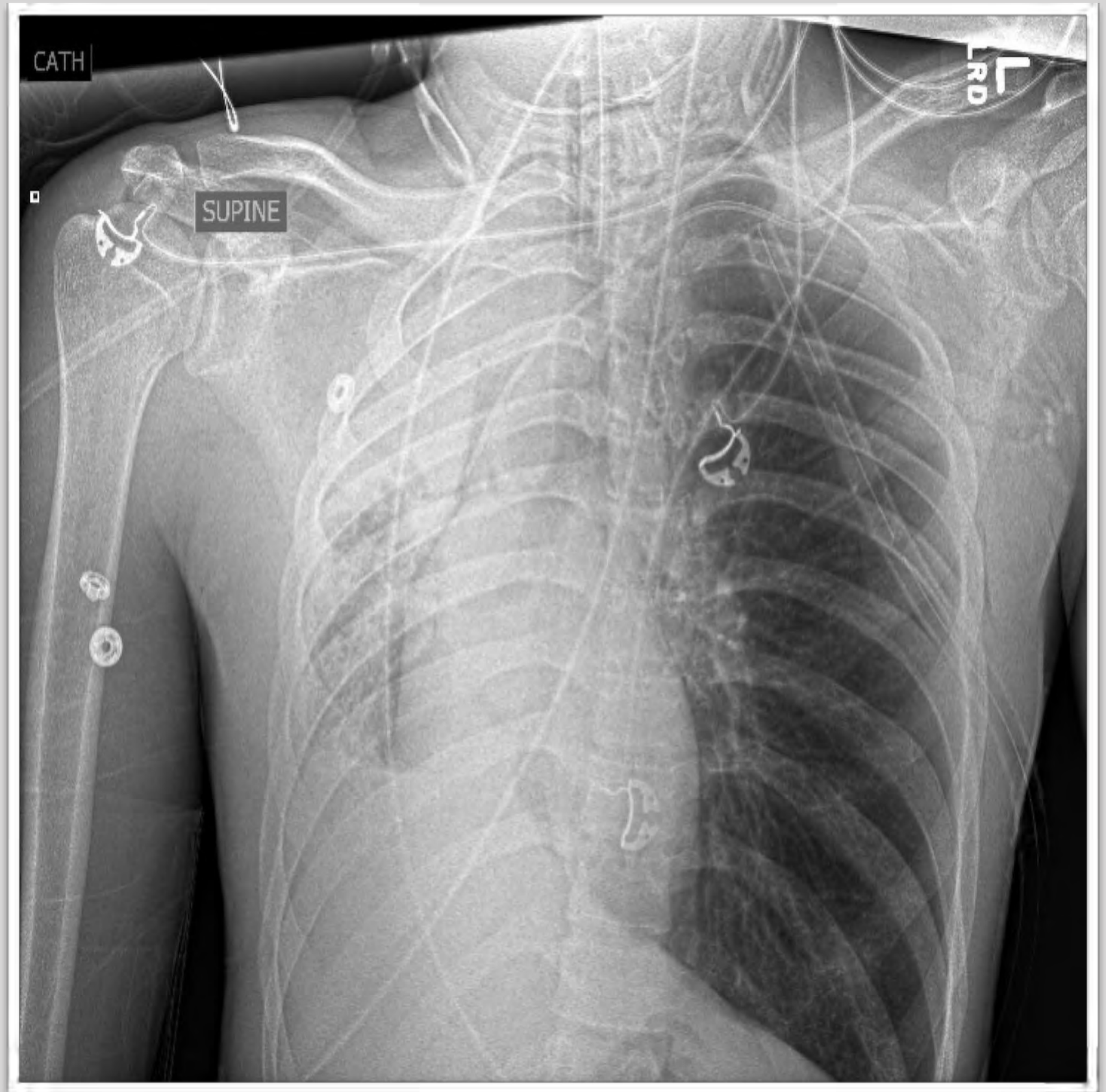


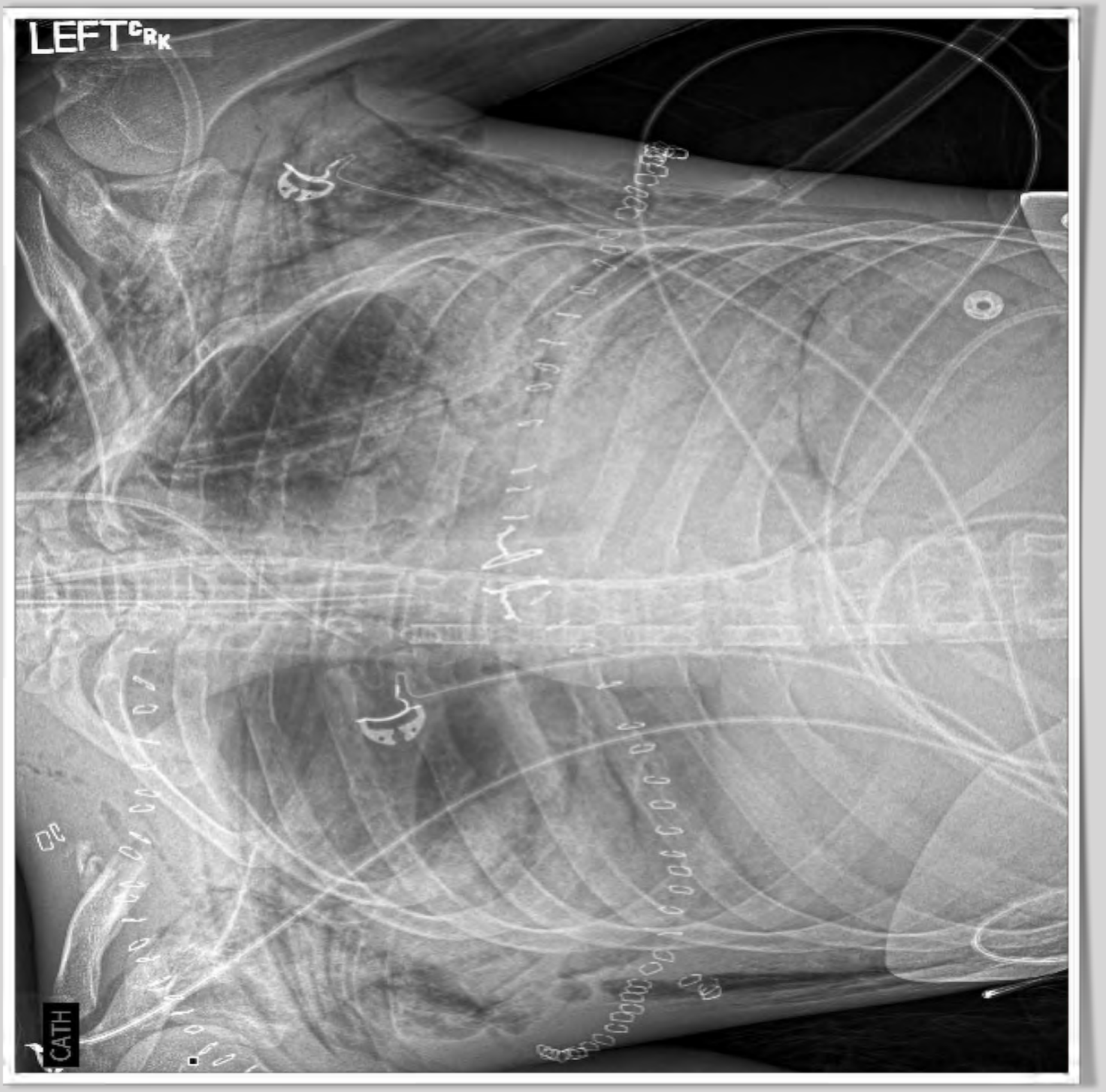
Christopher Patrick Henson, DO
Associate Professor, Vanderbilt University Medical Center
Department of Anesthesiology, Division of Anesthesiology Critical Care

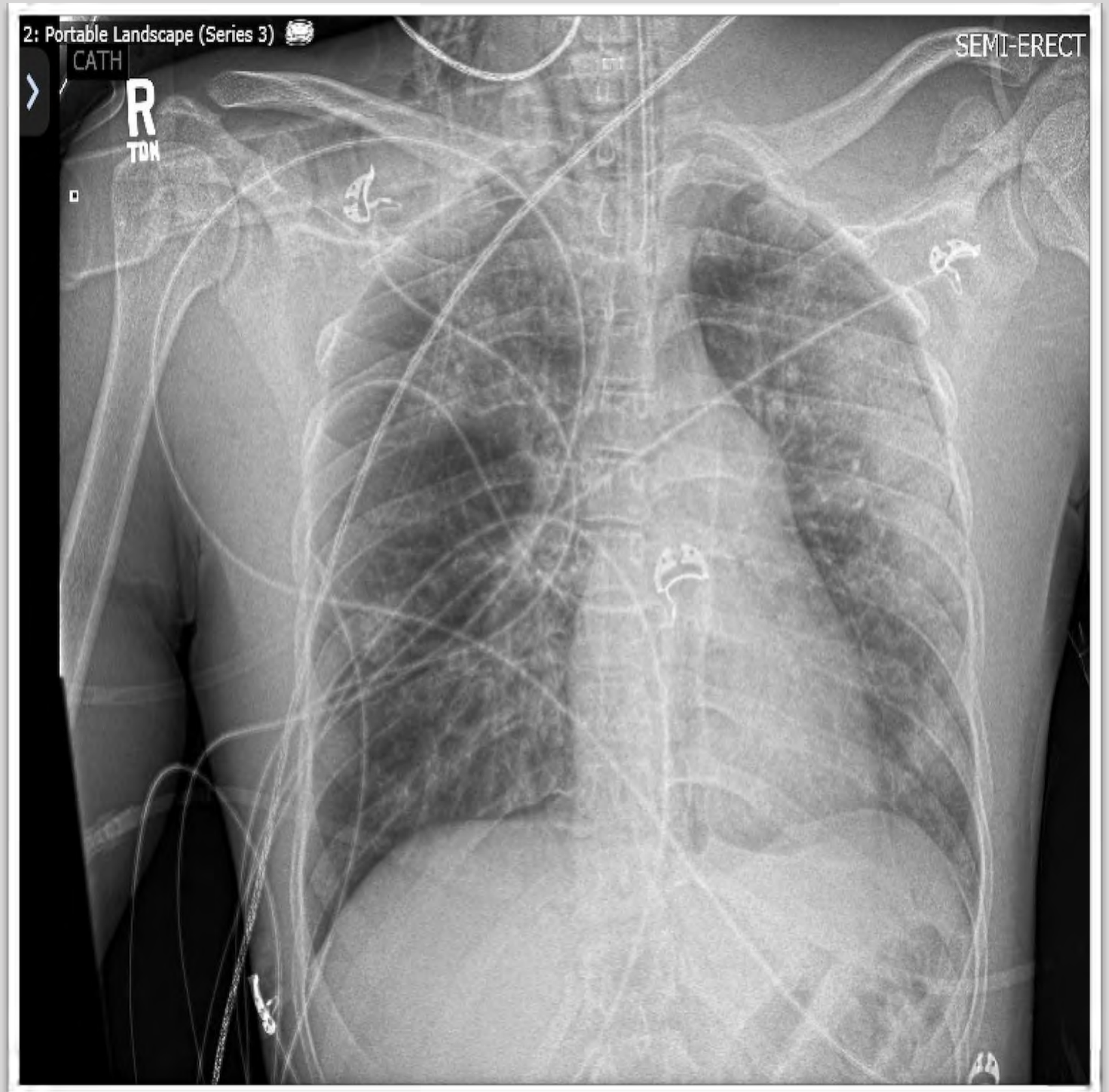
ECMO

TRAUMA

Christopher Patrick Henson, DO
Associate Professor, Vanderbilt University Medical Center
Department of Anesthesiology, Division of Anesthesiology Critical Care


CATH
SUPINE
LRD


LEFT CRK
CATH

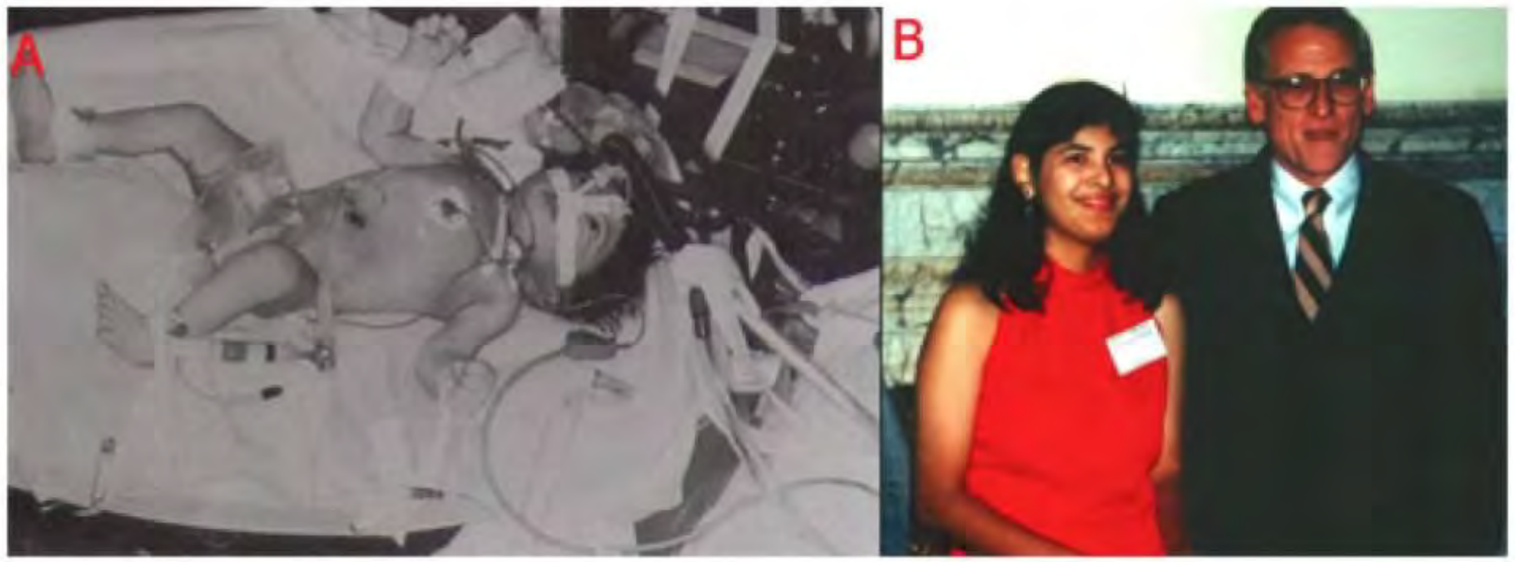

2: Portable Landscape (Series 3)
CATH
R
TDK
SEMI-ERECT

HISTORY

John Gibbon, first cardiopulmonary bypass case (1953)

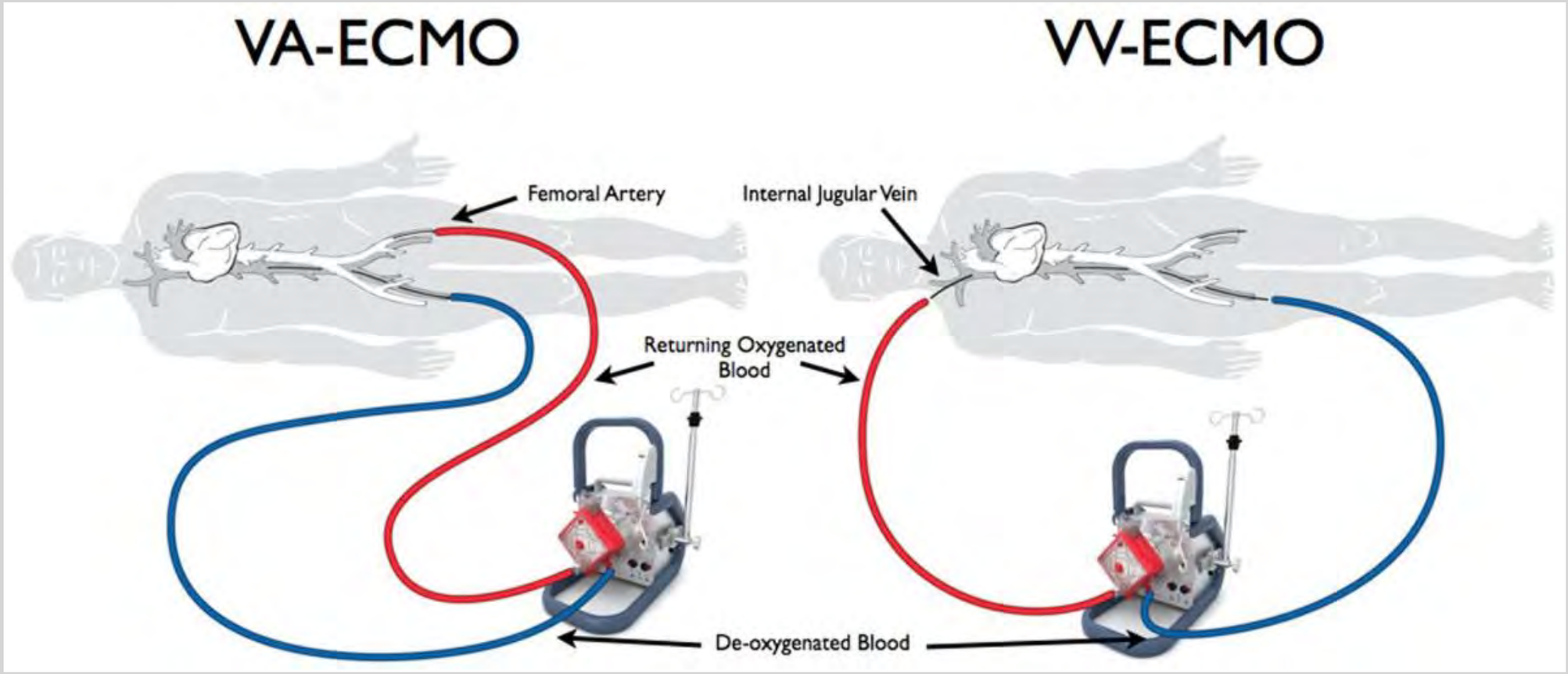
HISTORY

Baby Esperanza, 1974



Robert Bartlett and “Esperanza”, first neonatal ECMO survivor (1974)

ECMO



- VA ECMO can provide support to the failing heart as well as the lungs
- VV ECMO can only provide support to the failing lungs, but can help the heart (PVR reduction, coronary oxygenation, decreased RV strain)

Key physiologic concept: $DO_2 = CaO_2 \times CO$

INDICATIONS FOR VA ECMO

Maybe in order of practical benefit?

- **Advanced heart failure** (pre- and post-transplant as a way to protect organs, **primary graft dysfunction**)
- **Bridge to durable mechanical support** (allows time for LVAD workup)
- **Post-cardiotomy shock** (unable to wean CPB)
- **Cardiogenic shock** (post-MI, myocarditis, acute PE)
- **E-CPR** (during CPR (after ROSC?))
- **Toxic metabolic processes** (sepsis, poisons)

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- **Cardiogenic s** acute PE)
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HEART DONT WORK

INDICATIONS FOR VV ECMO

- **Hypoxic/hypercapneic respiratory failure** (ARDS, severe pneumonia, inhalation injury, fluid volume overload, aspiration, pancreatitis, etc.)

- **Very high ventilator settings** (etiology known or unknown)

- **Primary graft dysfunction following lung transplant**

- **Bridge to lung transplant** (best for people known to the system, work up started, etc.)

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- **Hypoxic/hypercapneic respiratory failure** (ARDS, severe pneumonia, inhalation injury, fluid volume overload, aspiration, pancreatitis, etc.)
- **Very high ver** own or unknown)
- **Primary graft** **g transplant**
- **Bridge to lung transplant** (best for people known to the system, work up started, etc.)

LUNGS DONT WORK

BENEFITS OF ECMO

- Support for the circulation
- Maintain cardiac output and blood pressure in a variety of situations
- Reduce need for high dose vasopressors and inotropes
  - Improves potential for cardiac recovery
- Provide life-sustaining oxygen
- Clear carbon dioxide and reduce acidosis
- Reduce need for high mechanical ventilation settings
  - Improves potential for pulmonary recovery

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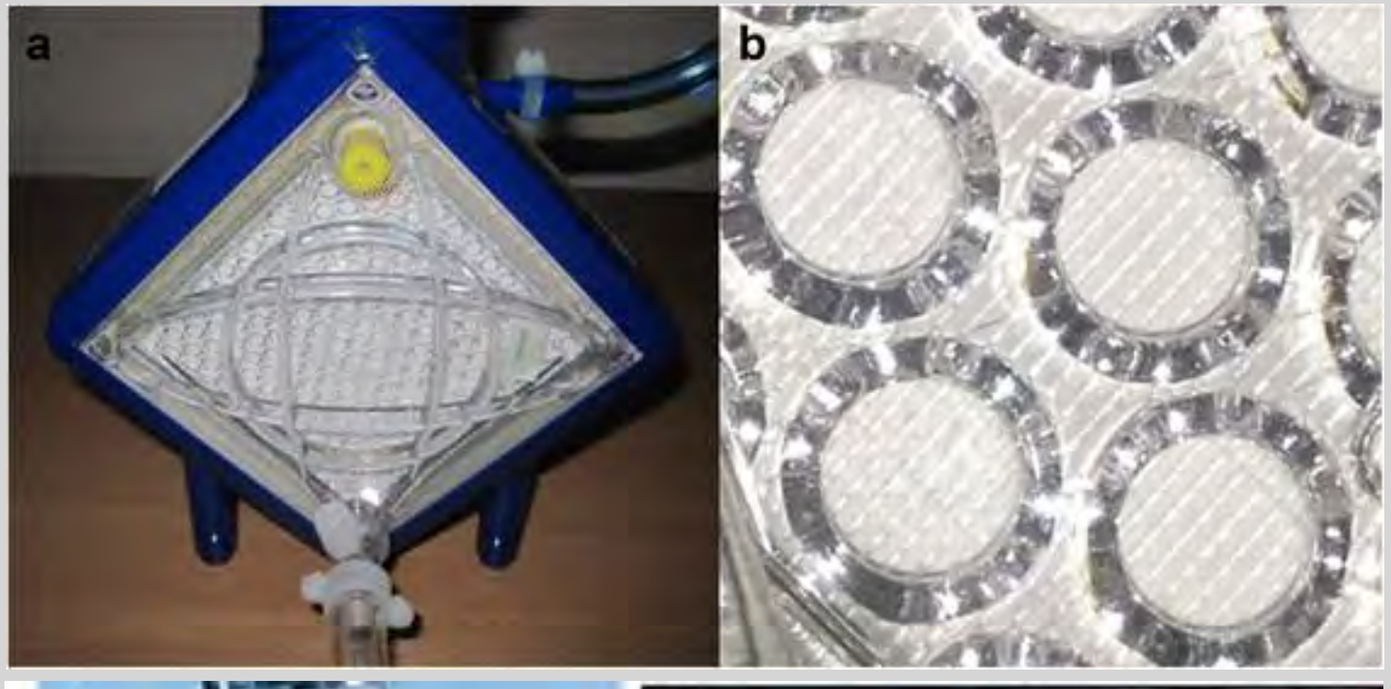
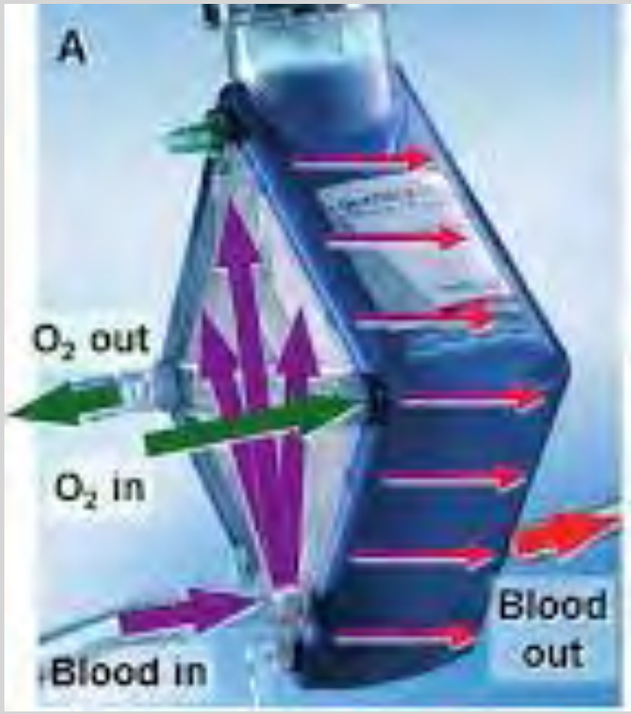
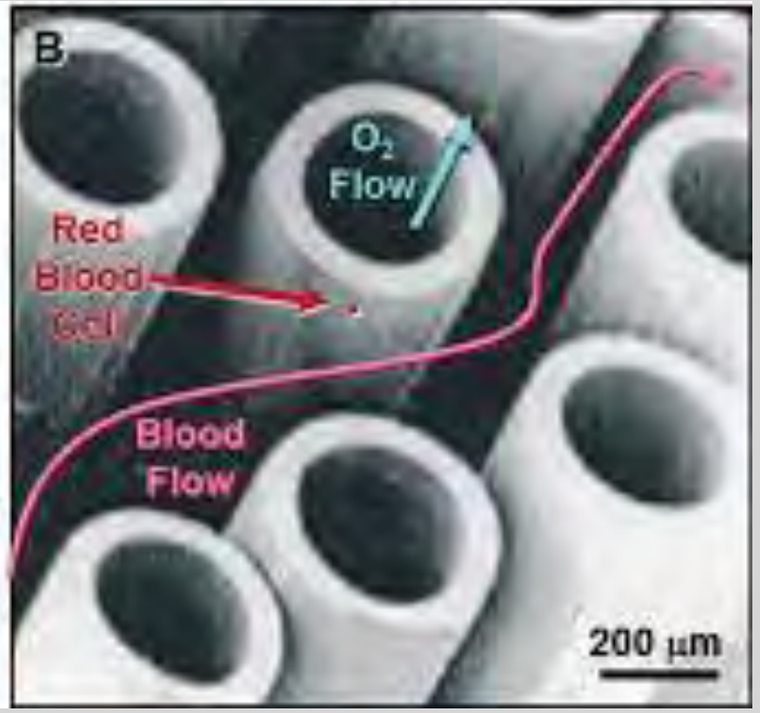
Mobile ECMO for cardiac arrest

ECMO at the Louvre



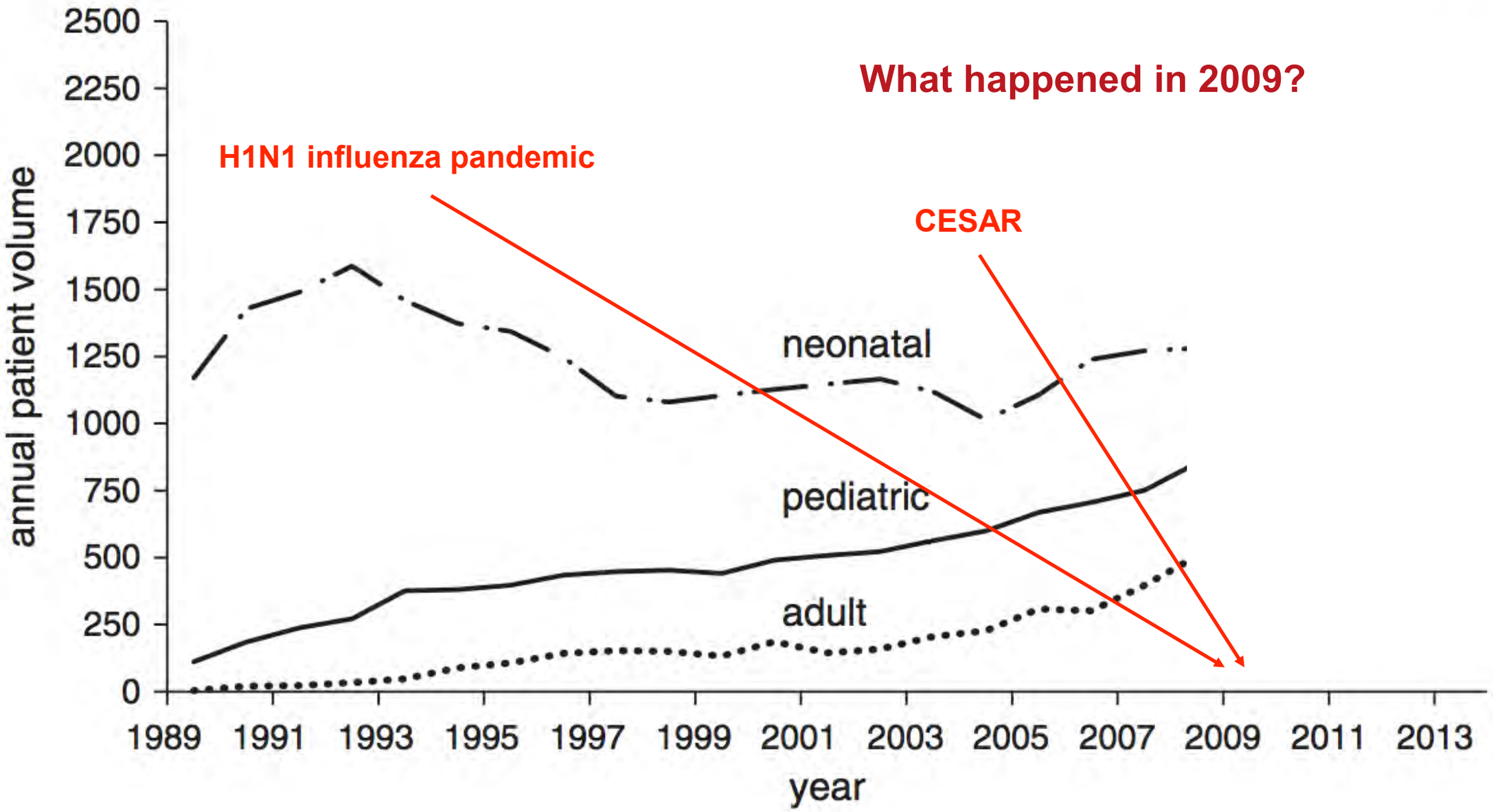




- **Countercurrent flow system**
- **Allows for addition of oxygen and clearance of CO2**
- **pH control, secondarily**
- **Minimal trauma to blood components**
- **Minimal clotting risk at high flows over short term**
- **Most important development to practical use of ECMO/bypass circuits**

Polymethylpentene oxygenators

ONLY FOR CHILDREN?

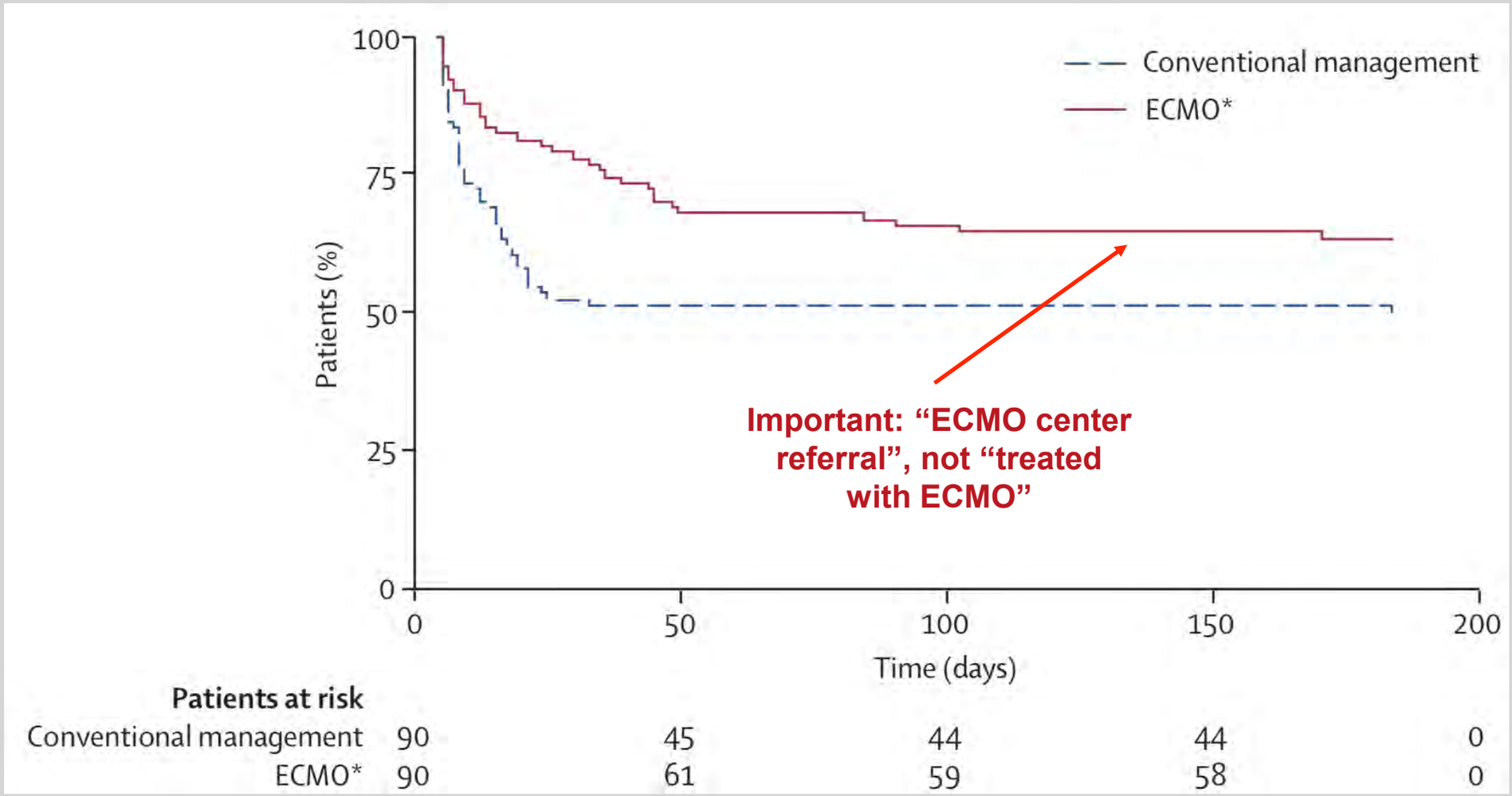


Barbaro RP, Odetola FO, Kidwell KM, et al. Association of hospital-level volume of extracorporeal membrane oxygenation cases and mortality. Analysis of the extracorporeal life support organization registry. Am J Respir Crit Care Med. 2015;191(8):894-901. doi:10.1164/rccm.201409-1634OC.

Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial

Giles J Peek, Miranda Mugford, Ravindranath Tiruvoipati, Andrew Wilson, Elizabeth Allen, Mariamma M Thalanany, Clare L Hibbert, Ann Truesdale, Felicity Clemens, Nicola Cooper, Richard K Firmin, Diana Elbourne, for the CESAR trial collaboration

Survival benefit when patients referred to ECMO center vs conventional mgmt



Peek, G. J., Mugford, M., Tiruvoipati, R., Wilson, A., Allen, E., Thalanany, M. M., et al. (2009). Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. *Lancet (London, England)*, *374*(9698), 1351–1363. http://doi.org/10.1016/S0140-6736(09)61069-2

ECMO for treatment but also transport

Pandemic and post-pandemic Influenza A (H1N1) infection in critically ill patients

Ignacio Martin-Loeches[1,2*], Emili Díaz[2], Loreto Vidaur[3], Antoni Torres[4], Cesar Laborda[5], Rosa Granada[6], Juan Bonastre[7], Mar Martín[8], Josu Insausti[9], Angel Arenzana[10], Jose Eugenio Guerrero[11], Ines Navarrete[12], Jesus Bermejo-Martin[13], David Suarez[14] and Alejandro Rodriguez[2], for the H1N1 SEMICYUC/RETPI/CIBERES Working group

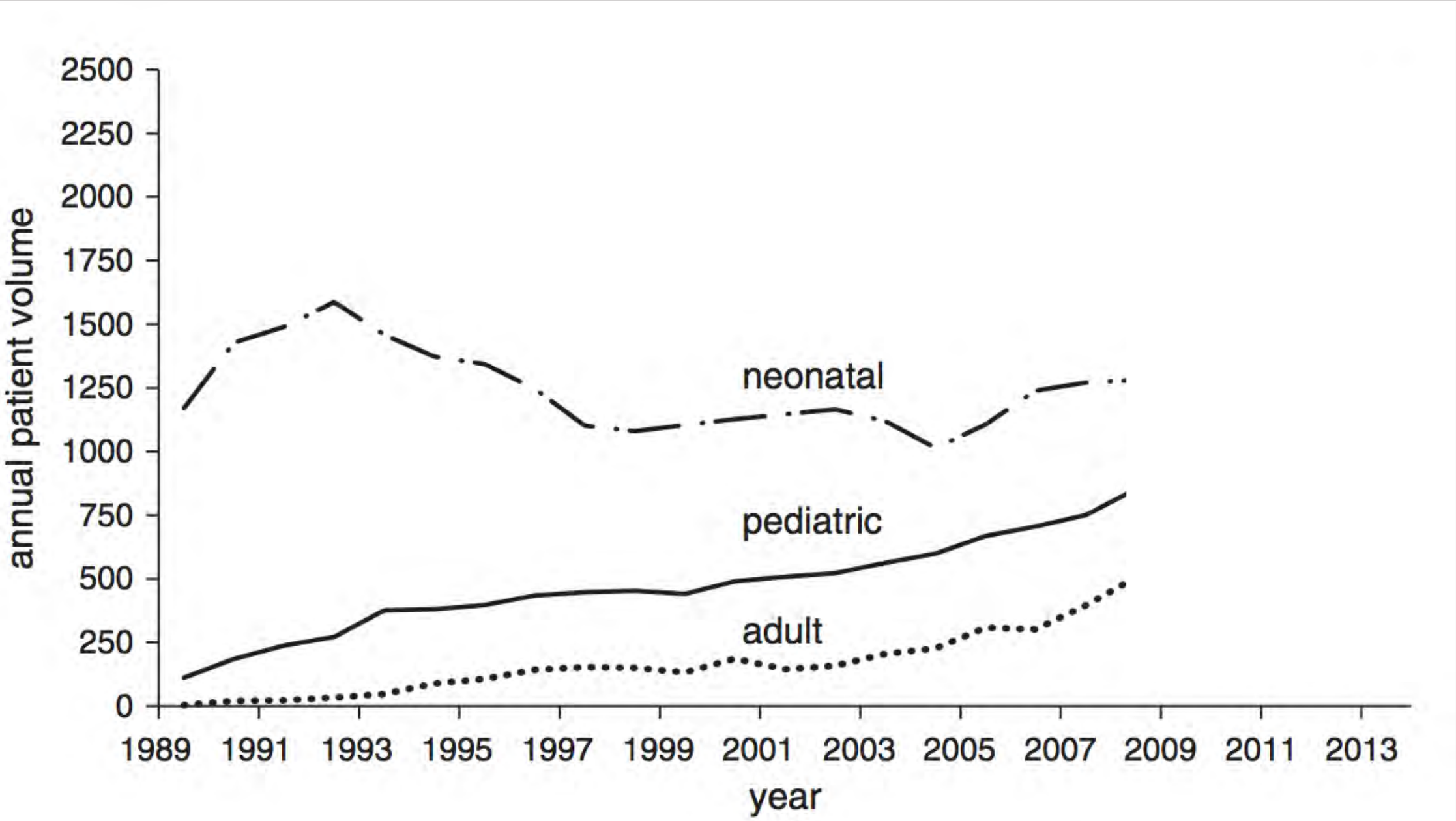
Martin-Loeches I, Díaz E, Vidaur L, et al. Pandemic and post-pandemic influenza A (H1N1) infection in critically ill patients. *Crit Care*. 2011;15(6):R286. doi:10.1186/cc10573.

Extracorporeal Membrane Oxygenation in the Context of the 2009 H1N1 Influenza A Pandemic

Kristen C. Sihler and Pauline K. Park

Sihler KC, Park PK. Extracorporeal membrane oxygenation in the context of the 2009 H1N1 influenza A pandemic. *Surg Infect*. 2011;12(2):151-158. doi:10.1089/sur.2010.082.

ONLY FOR CHILDREN?



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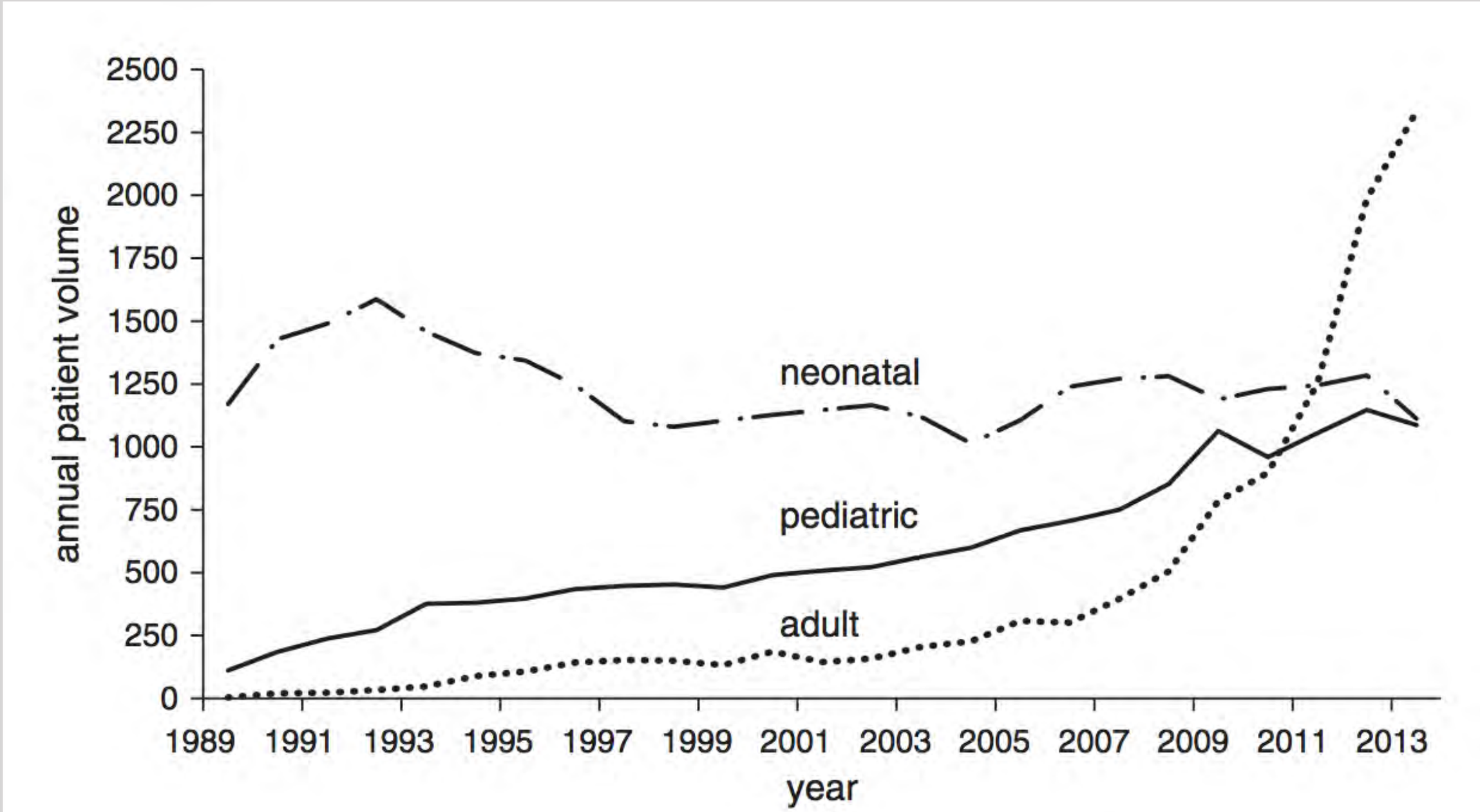

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INDICATIONS FOR VA ECMO

- Cardiac arrest
- Circulatory shock/hemodynamic instability/obstructive shock
- Periprocedural (potentially)
  - **HOWEVER…**

INDICATIONS FOR VA ECMO

- Cardiac arrest
- Circulatory shock/hemodynamic instability/obstructive shock
- Periprocedural (potentially)
  - **HOWEVER…**
  - **Not a great solution for distributive shock or hypovolemic shock**
  - **Wont help hemorrhage**
  - **Delay in application dramatically decreases success rate**

INDICATIONS FOR VV ECMO

Clincial Group/Reference	ELSO(2,16)	ECMOnet(20)	CESAR(17)	EOLIA NCT01470703
Indication to ECMO	Mortality risk > 80%: -P/F < 80 with FiO_2 > 0.90 -Murray score of 3-4	-OI > 30 -P/F < 70 with PEEP ≥ 15 cmH_2O for patients in an ECMO center -pH < 7.25 X ≥ 2 hrs -Hemodynamic instability	-Potentially reversible respiratory failure -Murray Score ≥ 3.0 -pH < 7.20 despite optimum conventional treatment	-P/F < 50 with FiO2 >0.8 X >3 hrs, -P/F <80 with FiO2 >0.8 for >6 hrs, -pH<7.25 for >6 hrs (RR increased to 35/min) with MV settings adjusted to keep Pplat <32 cmH_2O
Consideration for ECMO	-Mortality risk > 50%: -P/F < 150 with FiO_2 > 0.90 -Murray score of 2-3	P/F < 100 with PEEP ≥ 10 cmH_2O for patients awaiting transfer to an ECMO center	Murray score ≥2.5	

INDICATIONS FOR VV ECMO

Clincial Group/Refer					LIA 1470703
Indication to					h FiO2 >0.8
					h FiO2 >0.8
					>6 hrs (RR 35/min) with
					eep Pplat <32
Consideratio ECMO					

Murray score

= average score of all 4 parameters

Parameter / Score	0	1	2	3	4
PaO2/FIO2 (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	≤5	6-8	9-11	12-14	≥15
Compliance (ml/cmH2O)	≥80	60-79	40-59	20-39	≤19

Murray score 3 or greater = “maybe ECMO?”

Clinical trajectory important

CONTRAINDICATIONS FOR VV ECMO

Clincial Group/Reference	ELSO(2,16)	ECMOnet(20)	CESAR(17)	EOLIA NCT01470703
Contraindications to ECMO	-Conditions incompatible with normal life -Preexisting conditions affecting quality of life (CNS status, end stage malignancy, risk of systemic bleeding with anticoagulation) -Age -Futility: patients who are too sick (e.g., immunosuppression), have been on conventional therapy too long (MV >7 days)	-Intracranial bleeding -Other contraindication to anticoagulation -Previous severe disability -Poor prognosis of underlying disease -Mechanical ventilation > 7 days.	-Peak inspiratory pressure >30 cmH_2O -FiO_2 >0.8 -Ventilation for > 7 days -Intracranial bleeding -Contraindication to anticoagulation -Contraindication to continuation of active treatment	-MV ≥ 7 days -Age < 18 years -Pregnancy -BMI > 45 kg/m^2 -Chronic respiratory insufficiency treated with long duration oxygen or respiratory assistance -Previous history of HIT -Malignancy with fatal prognosis within 5 years -Patient moribund -SAPS II > 90 -Non drug-induced coma following cardiac arrest -Irreversible neurological pathology -ECMO cannulation not possible

CONTRAINDICATIONS FOR ECMO

- Cannulation impossible or unwise
- Are there really any others?

CONTRAINDICATIONS FOR ECMO

- Cannulation impossible or unwise
- Are there really any others?
- General rules
  - **Younger patients do better**
  - **Less sick patients do better**
  - **Patients with defined exit strategies do better**

CONTRAINDICATIONS FOR ECMO

- Cannulation impossible or unwise

IMPORTANT TO REMEMBER: "BETTER" IS OFTEN PATIENT-SPECIFIC - "WHAT DOES RECOVERY FROM THIS ORGAN INJURY LOOK LIKE FOR MY PATIENT?" IS IMPORTANT QUESTION TO ASK

CONTRAINDICATIONS FOR ECMO

What do I think about when being consulted?

CONTRAINDICATIONS FOR ECMO

- Age and underlying conditions, other organ injury/failure
- Unrecoverable cardio/pulmonary function, not candidate for transplant/durable support
- Prolonged cardiopulmonary resuscitation (CPR) without adequate tissue perfusion
- Duration of illness/mechanical ventilation
- Inability to fully anticoagulate
- **“What’s the exit strategy?”**

What do I think about when being consulted?

RISKS OF ECMO

- Renal failure requiring CVVH (52%)
- Bacterial pneumonia (33%)
- Any bleeding (33%)
- Oxygenator dysfunction/replacement (29%)
- Sepsis (26%)
- Hemolysis (18%)
- Liver dysfunction (16%)
- Leg ischemia (10%)
- Venous thrombosis (10%)
- Central nervous system complications (8%)
- Gastrointestinal bleeding (5%)
- DIC (5%)

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- Gastrointestinal bleeding (5%)
- **DIC (5%)**

BOLD = more ECMO-specific

WHAT ARE THE COMPONENTS OF CARE?

- **Facility**
  - Many different sizes, mostly larger referral centers

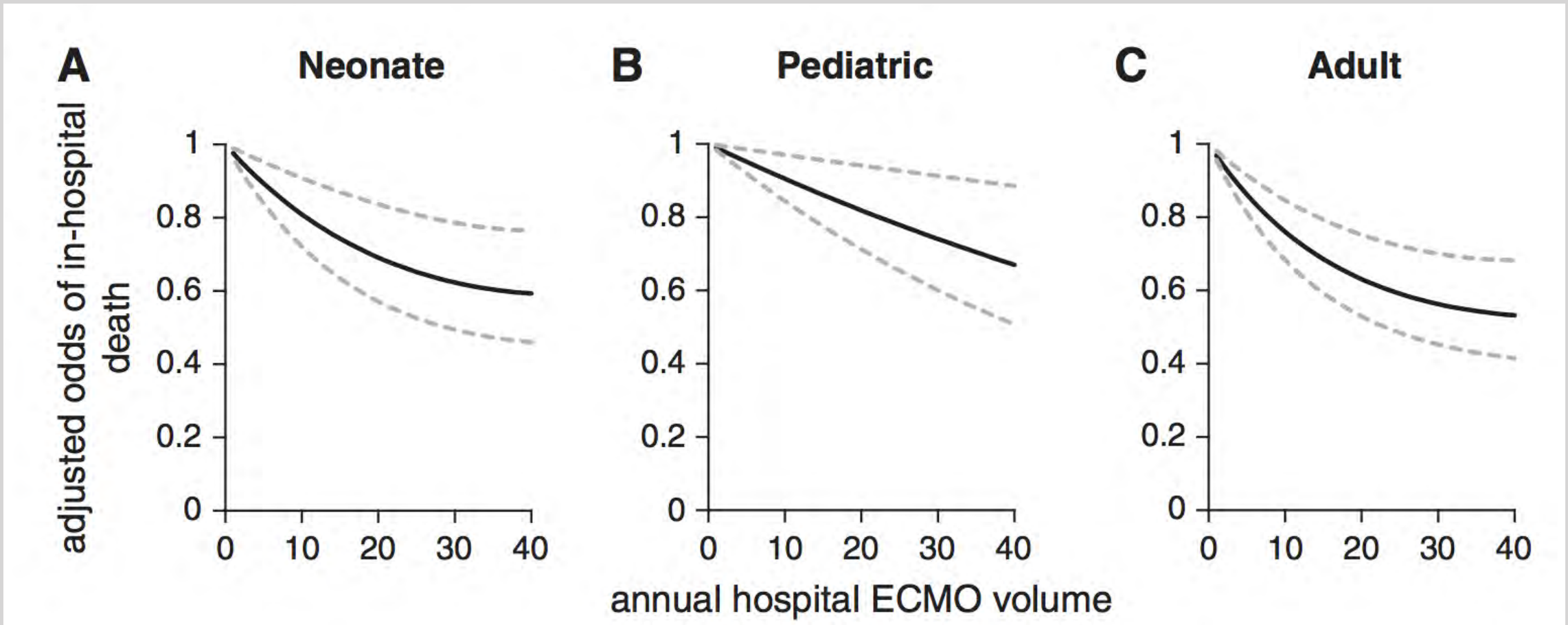
- **People**
  - Skilled nurses, perfusionists
  - Physicians
    - In-house or on-call ICU physicians, cardiac surgeons
  - Ancillary staff
    - RT, PT/OT, lab, blood bank, consultants

- **Equipment**

Association of Hospital-Level Volume of Extracorporeal Membrane Oxygenation Cases and Mortality

Analysis of the Extracorporeal Life Support Organization Registry

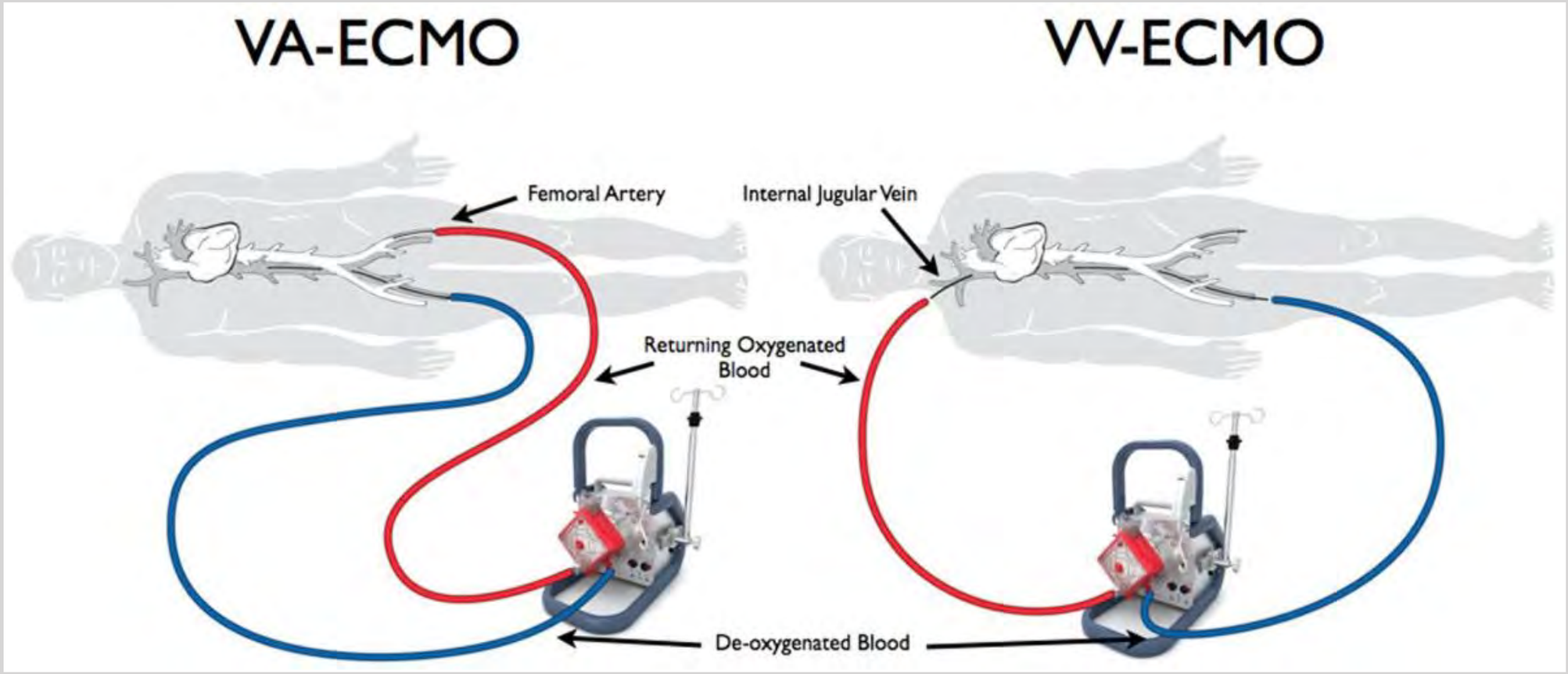
Ryan P. Barbaro[1,2], Folafoluwa O. Odetola[1,2], Kelley M. Kidwell[3], Matthew L. Paden[4], Robert H. Bartlett[5], Matthew M. Davis[2,6,7,8,9*], and Gail M. Annich[10*]



Higher ECMO volume associated with lower mortality

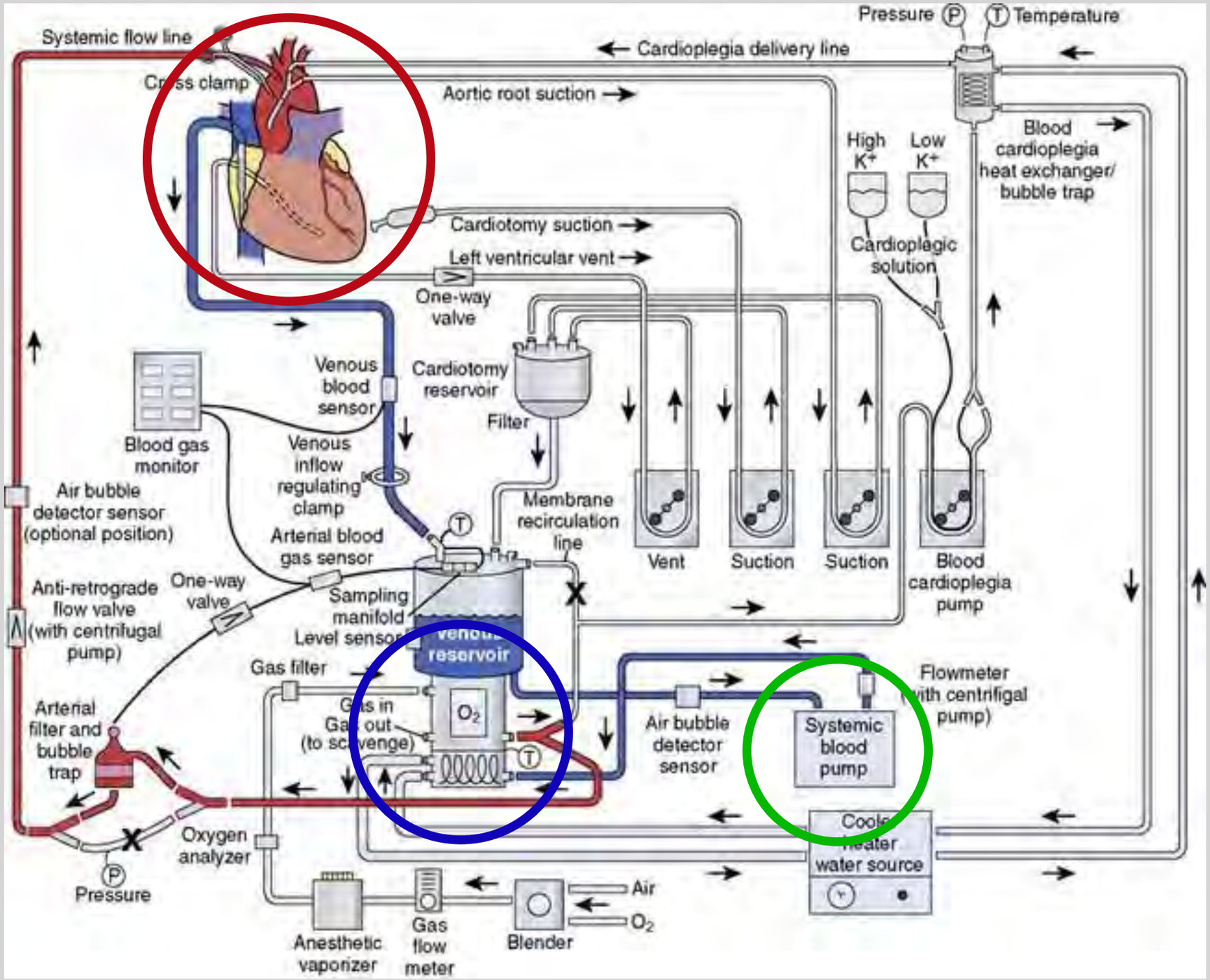
Barbaro RP, Odetola FO, Kidwell KM, et al. Association of hospital-level volume of extracorporeal membrane oxygenation cases and mortality. Analysis of the extracorporeal life support organization registry. *Am J Respir Crit Care Med*. 2015;191(8):894-901. doi:10.1164/rccm.201409-1634OC.

TO REVISIT



Not pictured: oxygen source

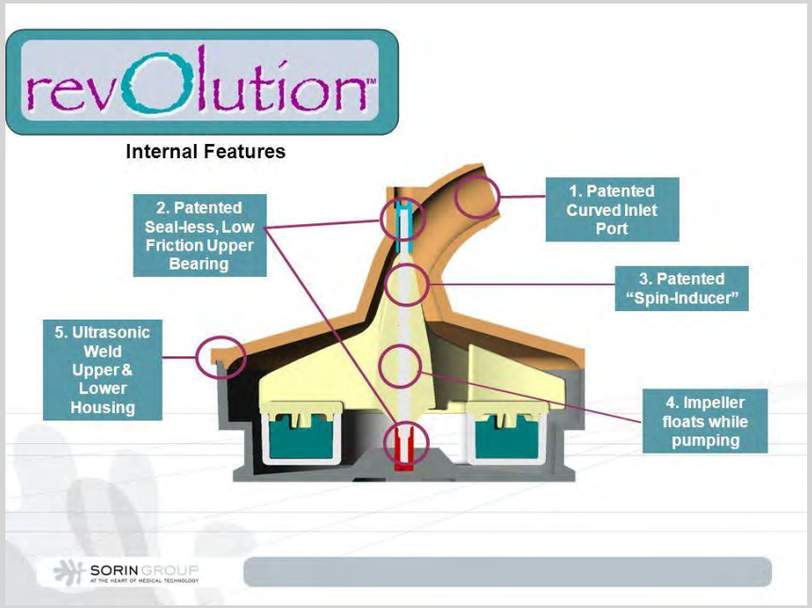
EQUIPMENT



What do we really need?

- **Access to the circulation/tubing**
- **Pump to provide mechanical support of blood flow**
- **Ability to provide gas exchange/oxygenator**

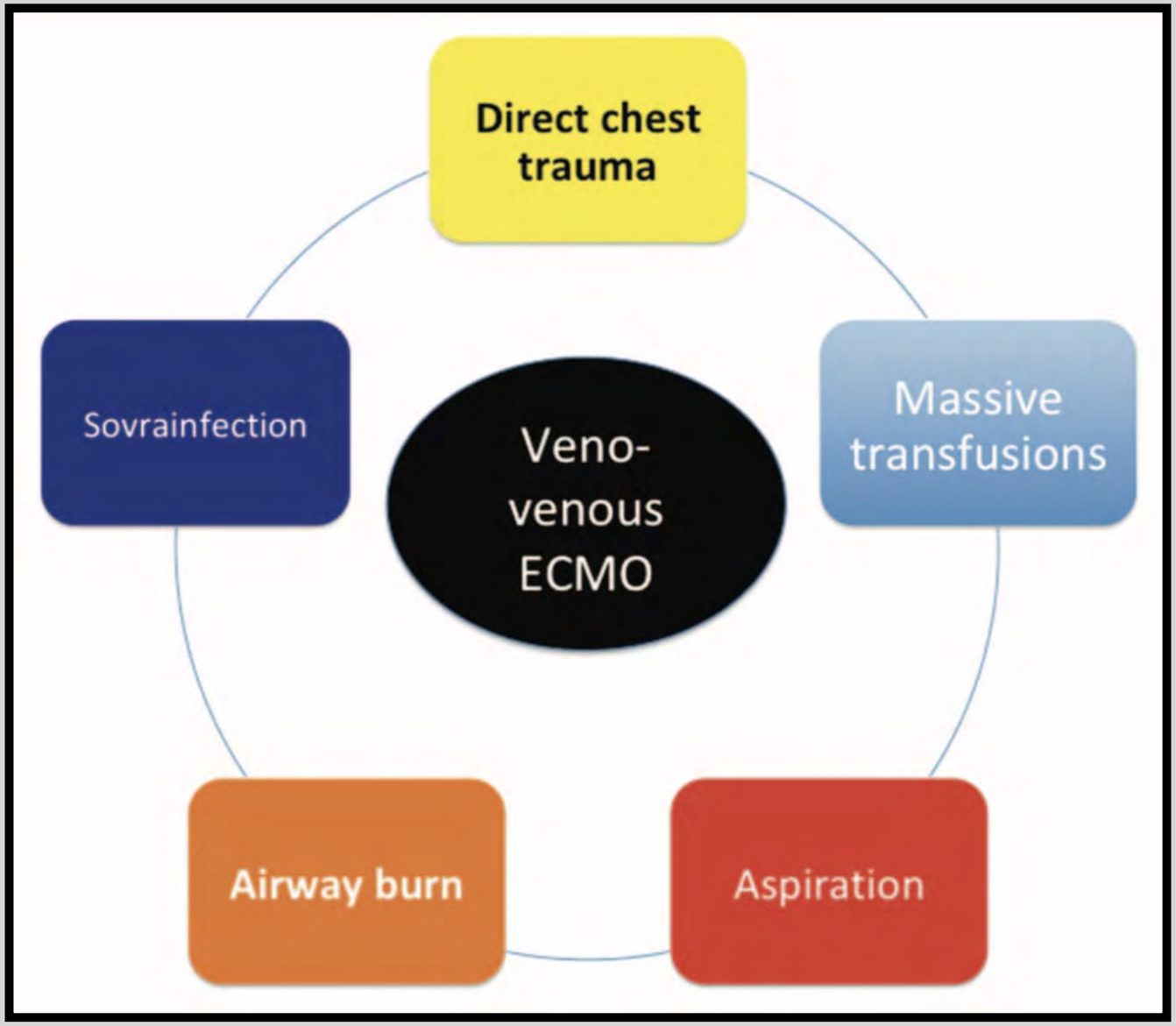
ECMO PUMPS


revOlution
Internal Features
1. Patented Curved Inlet Port
2. Patented Seal-less, Low Friction Upper Bearing
3. Patented "Spin-Inducer"
4. Impeller floats while pumping
5. Ultrasonic Weld Upper & Lower Housing
SORIN GROUP

Extra corporeal membrane oxygenation in the critical trauma patient

Valentina Della Torre[a,*], *Chiara Robba*[b,*], *Paolo Pelosi*[b,c], *and Federico Bilotta*[d]

Why would a trauma patient need VV ECMO?



Torre Della V, Robba C, Pelosi P, Bilotta F. Extra corporeal membrane oxygenation in the critical trauma patient. *Current Opinion in Anaesthesiology*. 2019;32(2):234-241. doi:10.1097/ACO.0000000000000698.

Extra corporeal membrane oxygenation in the critical trauma patient

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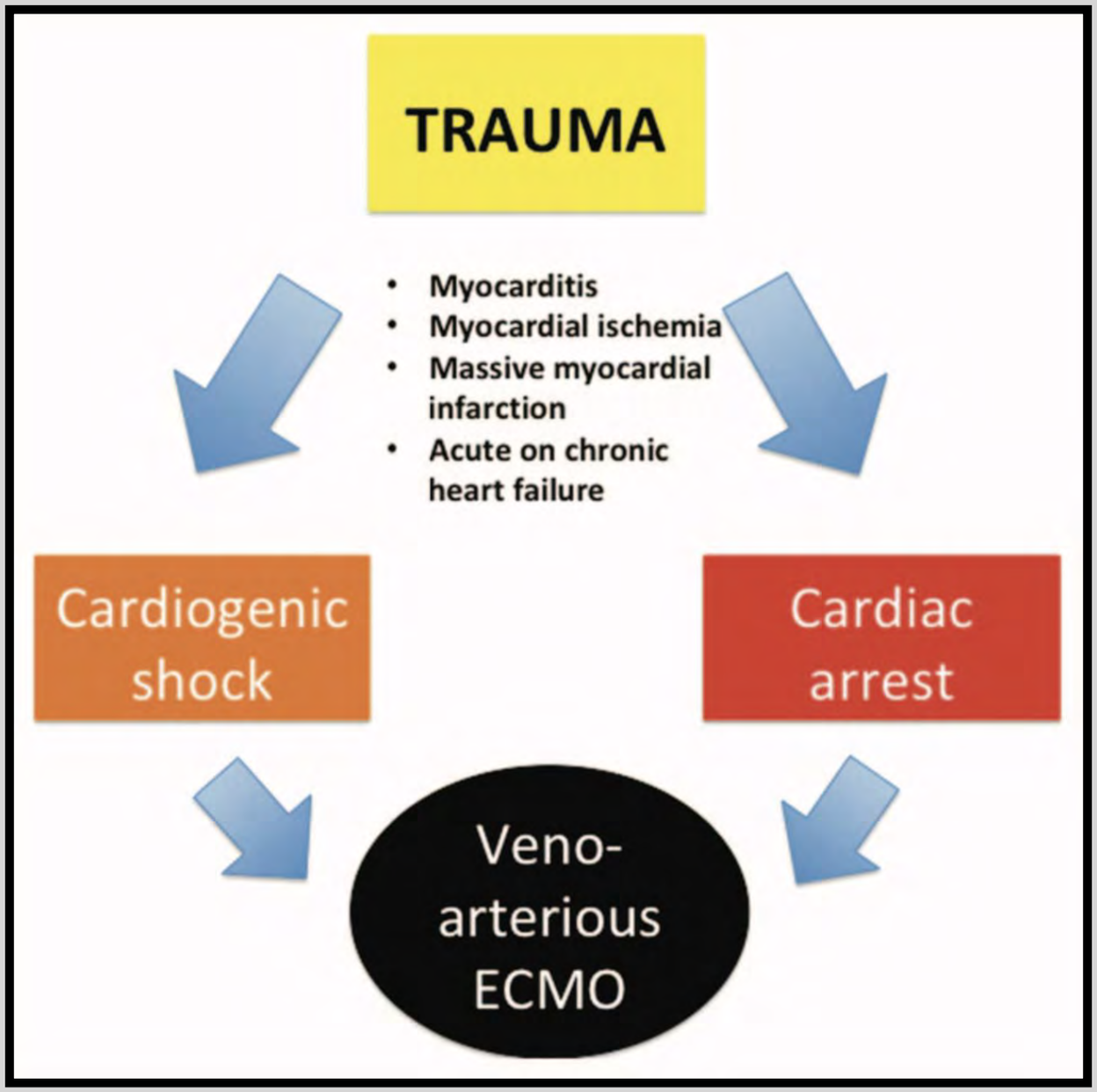

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SHOULD I CONSIDER ECMO?

The nature of lung injury may be poorly defined and etiology unknown. VV ECMO may be something to consider in trauma patients without full understanding of the causes or trajectory.

Proper consideration of VA ECMO for circulatory shock (in all patients, but specifically in trauma patients) should involve the understanding of ‘why’ (cardiac contusion, PE, periprocedural support) with more clearly defined endpoints (‘how are we going to get better’)

SHOULD I CONSIDER ECMO?

The nature of lung injury may be poorly defined and etiology unknown. VV ECMO may be something to consider in trauma patients without full understanding of

MAYBE ASK WHY WOULDNT THEY NEED ECMO?

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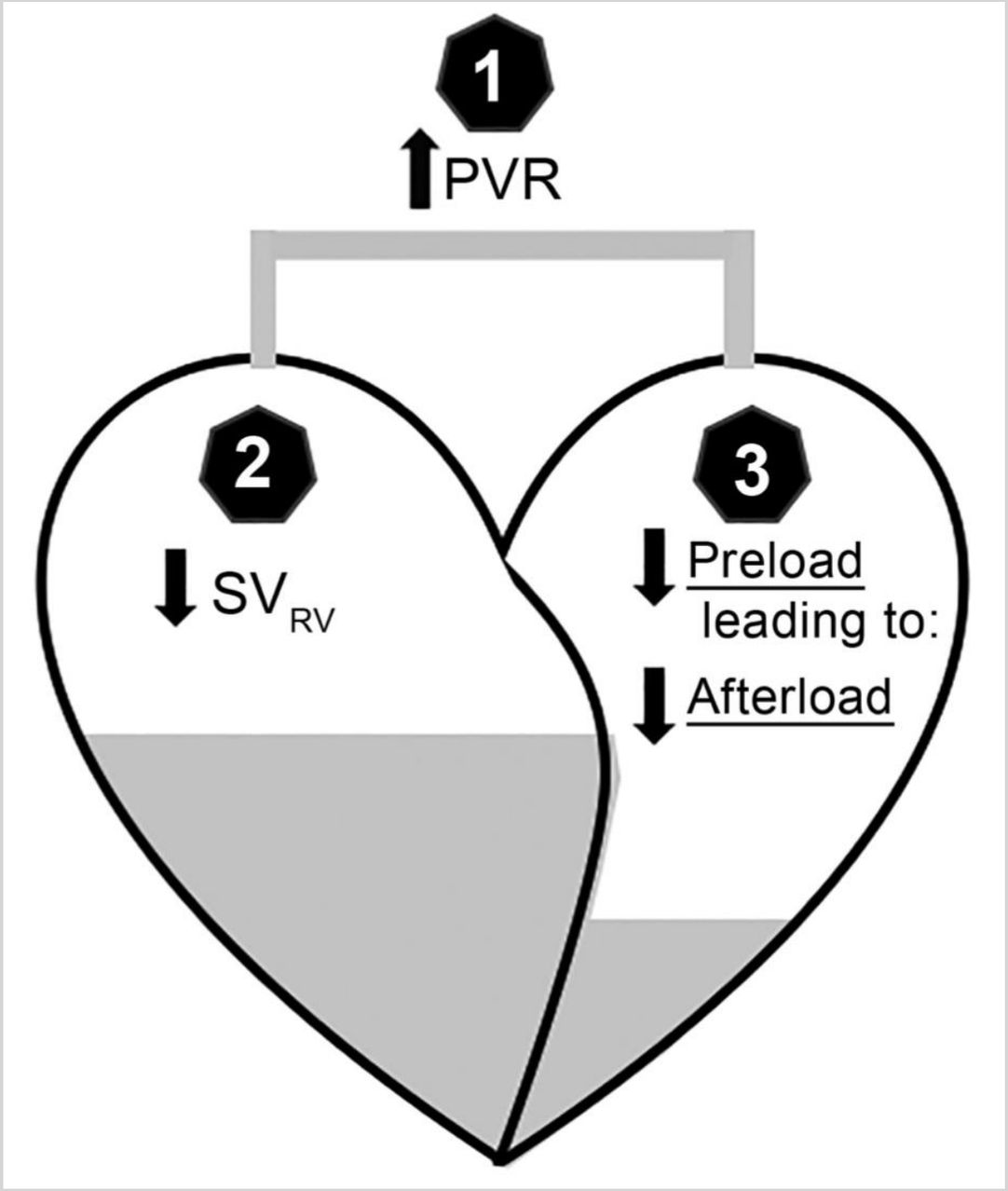
WHAT THINGS MIGHT HAPPEN PRIOR TO ECMO?

https://www.arjo.com/en-us/products/medical-beds/critical-care/rotoprone/

WHY ARE ARDS PATIENTS HYPOTENSIVE?

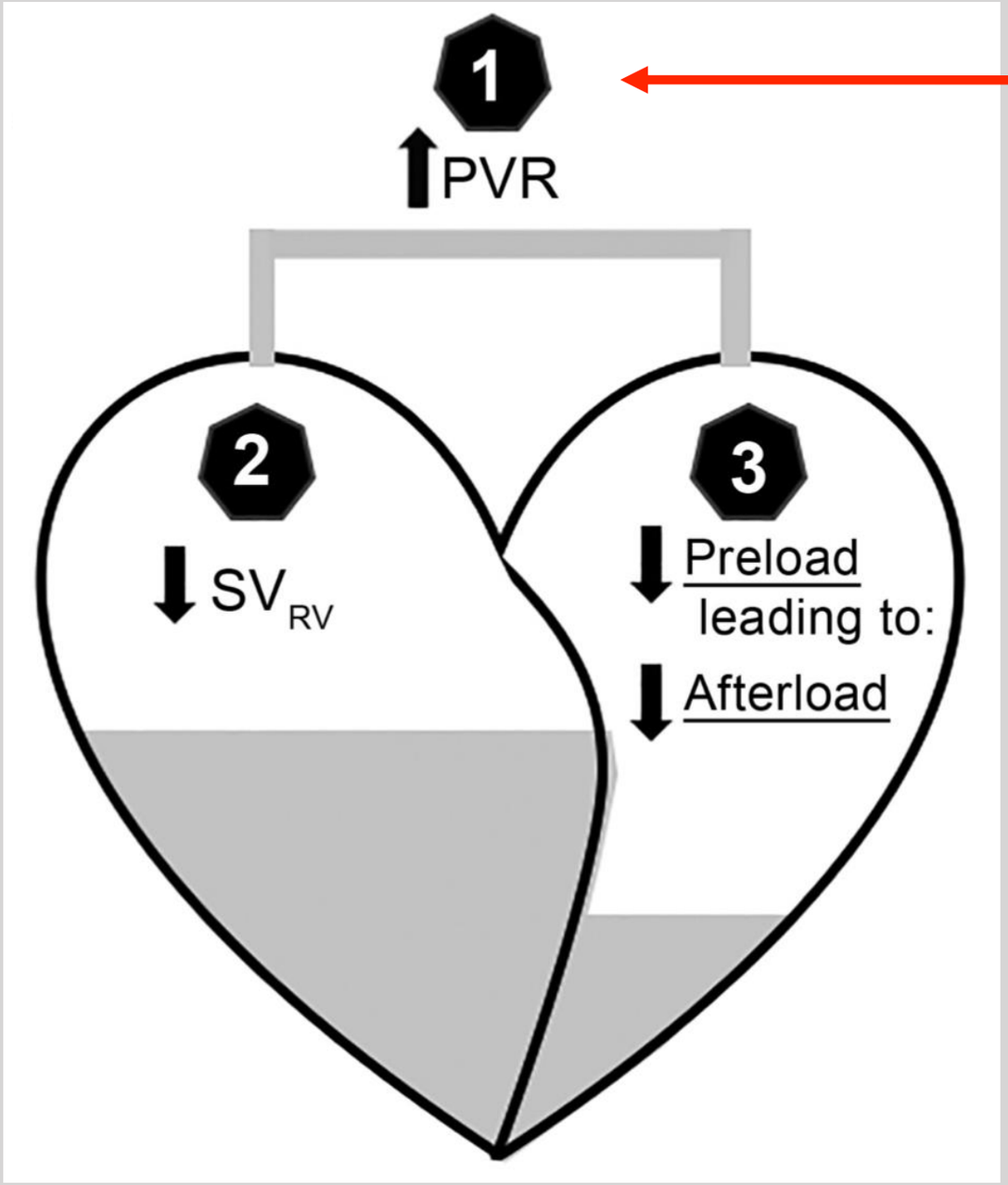
(Important physiology interlude)

CARDIOPULMONARY INTERACTIONS



Verhoeff K, Mitchell JR. Cardiopulmonary physiology: why the heart and lungs are inextricably linked. *Adv Physiol Educ*. 2017;41(3):348-353. doi:10.1152/advan.00190.2016.

CARDIOPULMONARY INTERACTIONS



Hypoxia, hypercarbia, acidosis, high vent settings, LV dysfunction all ↑↑↑ PVR

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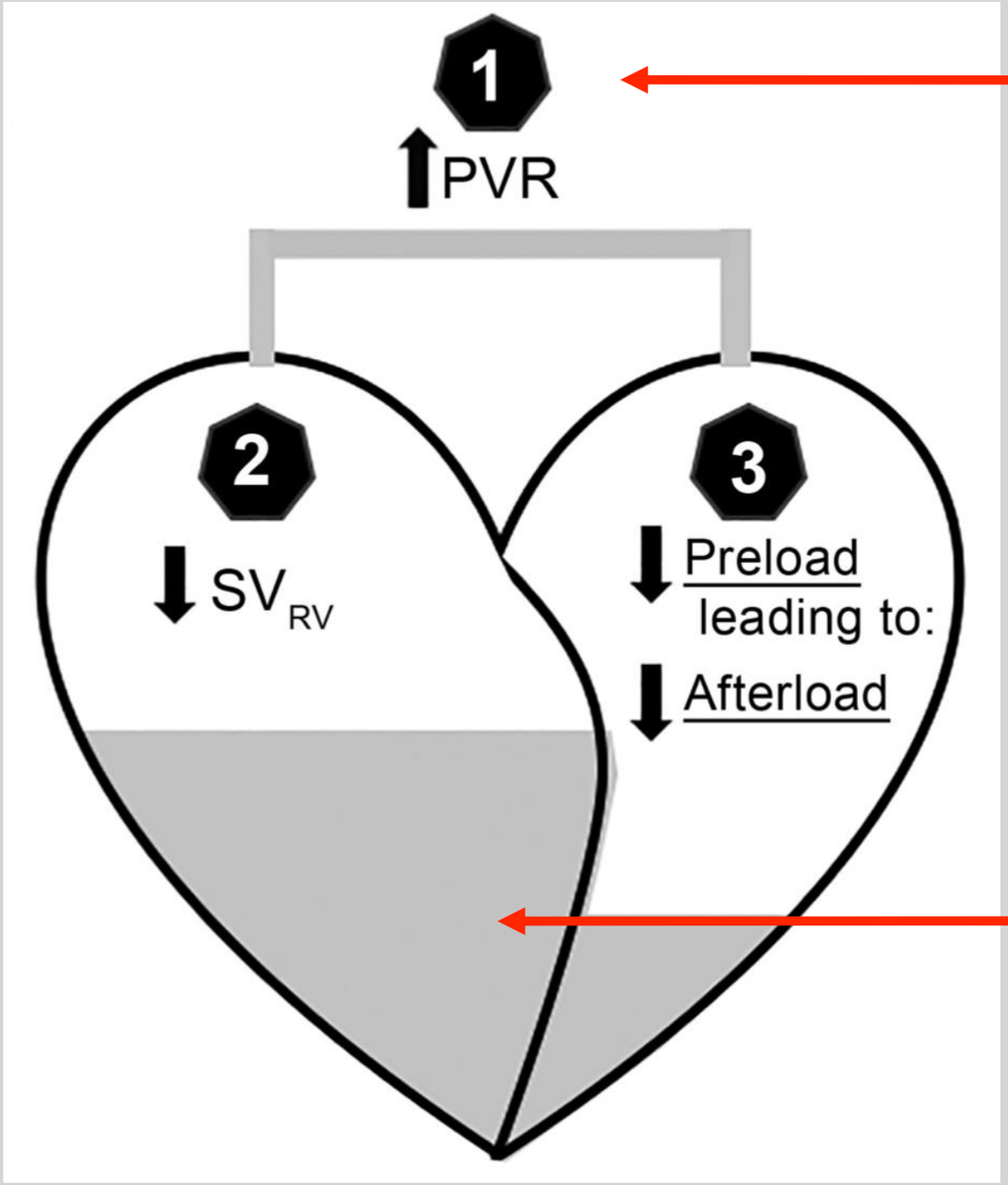

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RV dysfunction secondary to ↑↑↑ PVR worsens cardiac output, hypotension

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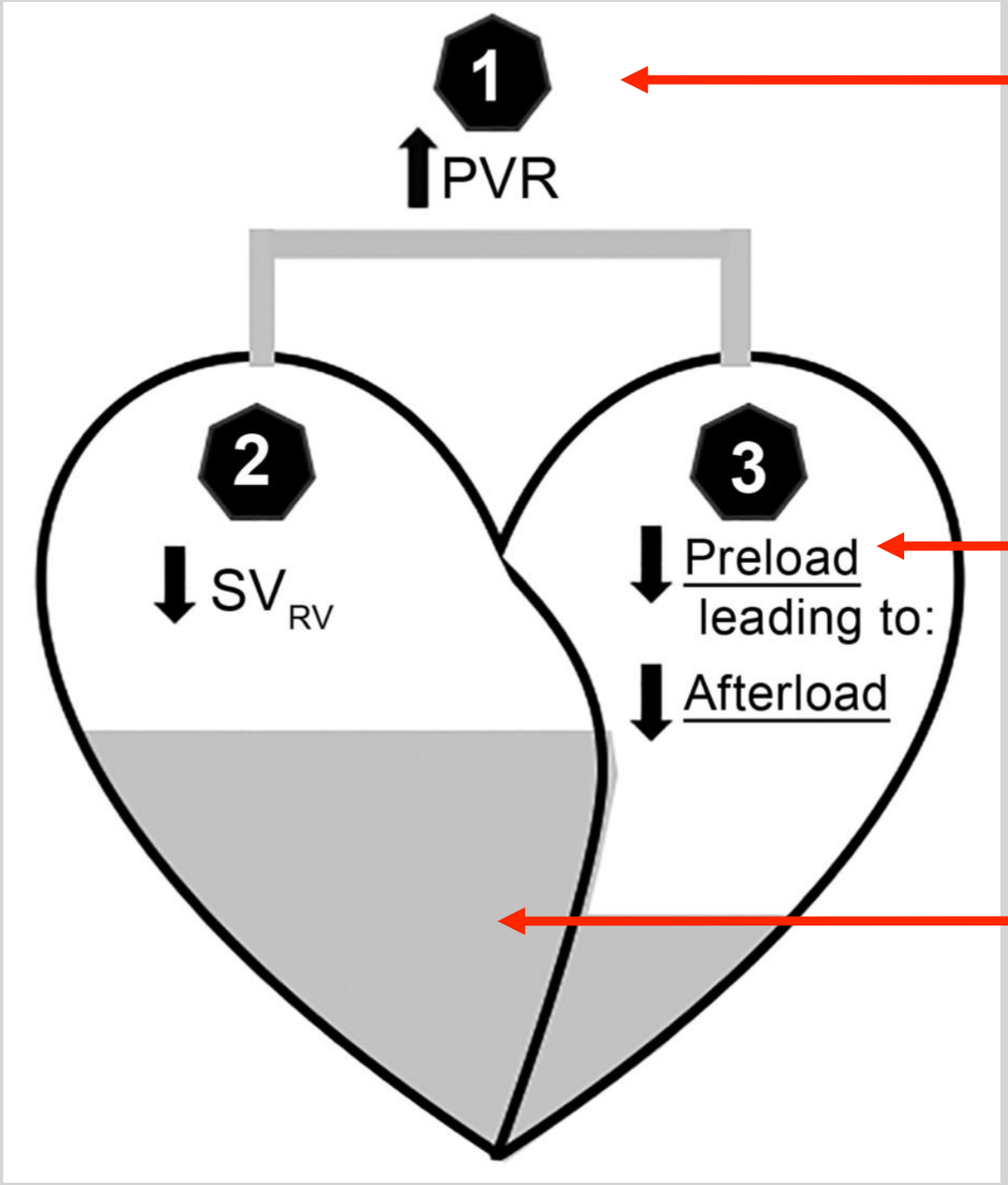

Hypoxia, hypercarbia, acidosis, high vent settings, LV dysfunction all ↑↑↑ PVR

LV dysfunction from hypoxia, ischemia, RV geometry changes

RV dysfunction secondary to ↑↑↑ PVR worsens cardiac output, hypotension

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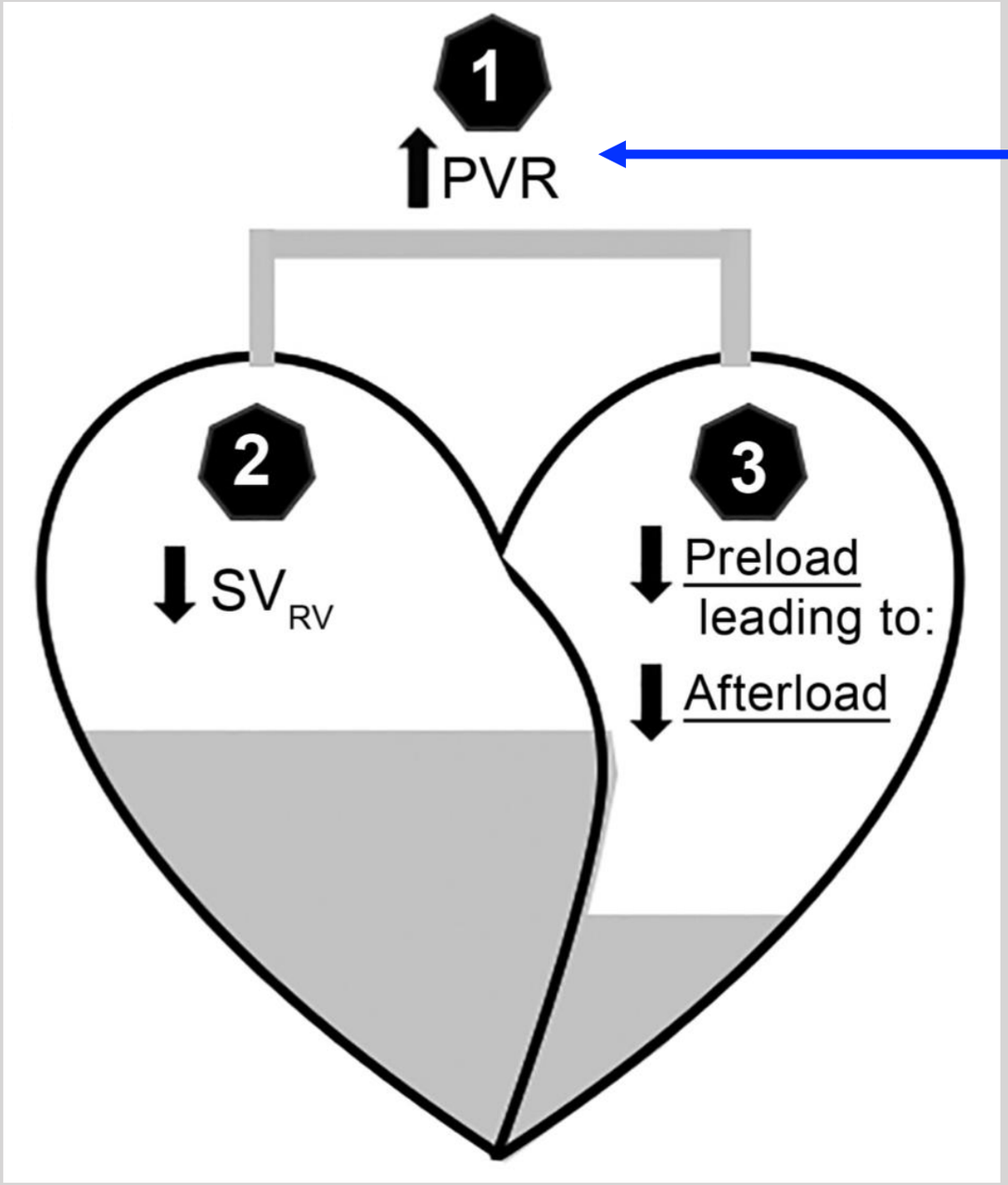
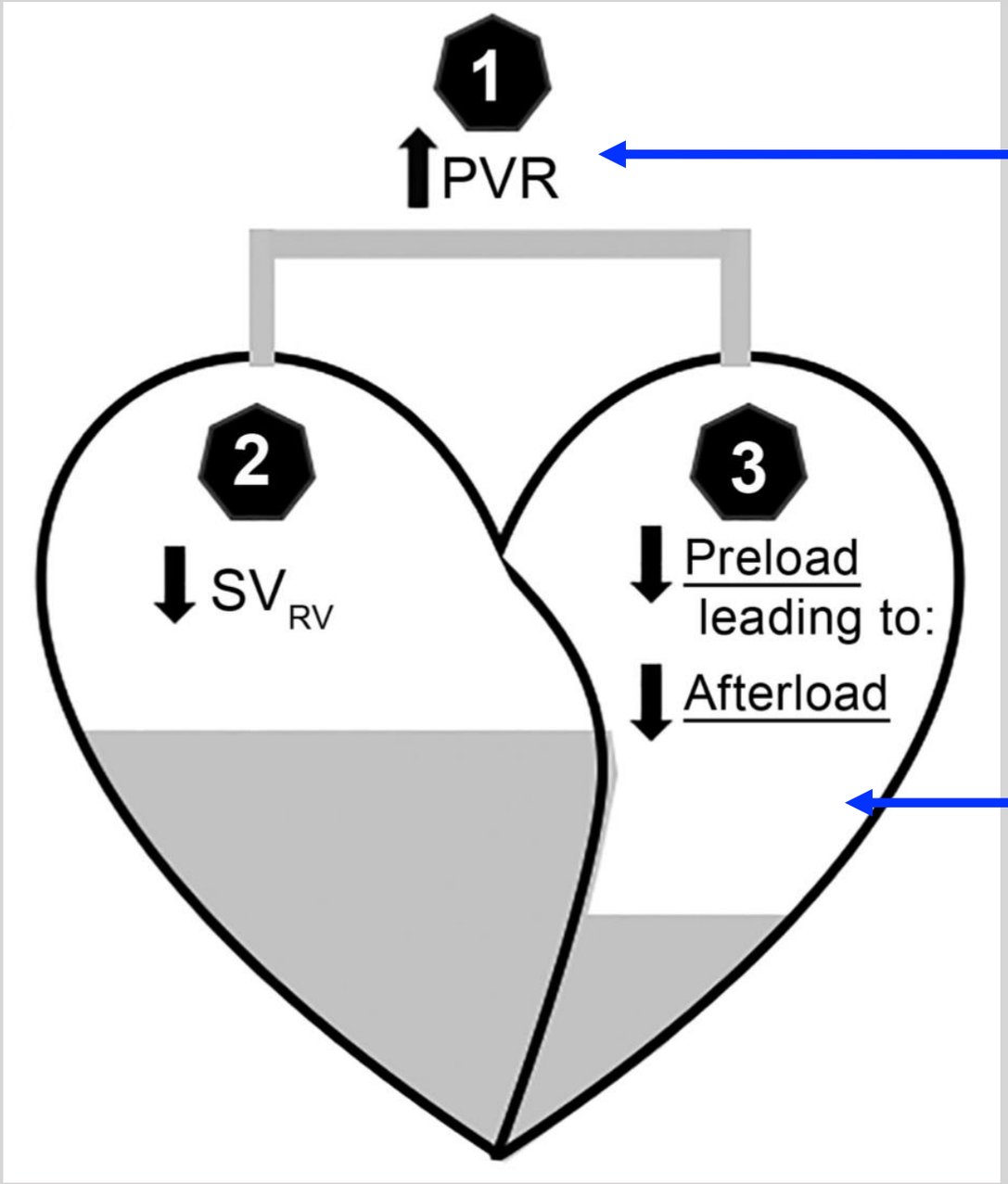


Delivering oxygenated blood to the pulmonary circulation can offset PVR rise, easing RV strain, improve hemodynamics

Verhoeff K, Mitchell JR. Cardiopulmonary physiology: why the heart and lungs are inextricably linked. *Adv Physiol Educ*. 2017;41(3):348-353. doi:10.1152/advan.00190.2016.

CARDIOPULMONARY INTERACTIONS



Delivering oxygenated blood to the pulmonary circulation can offset PVR rise, easing RV strain, improve hemodynamics

Relieving RV strain improves LV filling, delivering oxygenated blood to the coronaries can improve LV function

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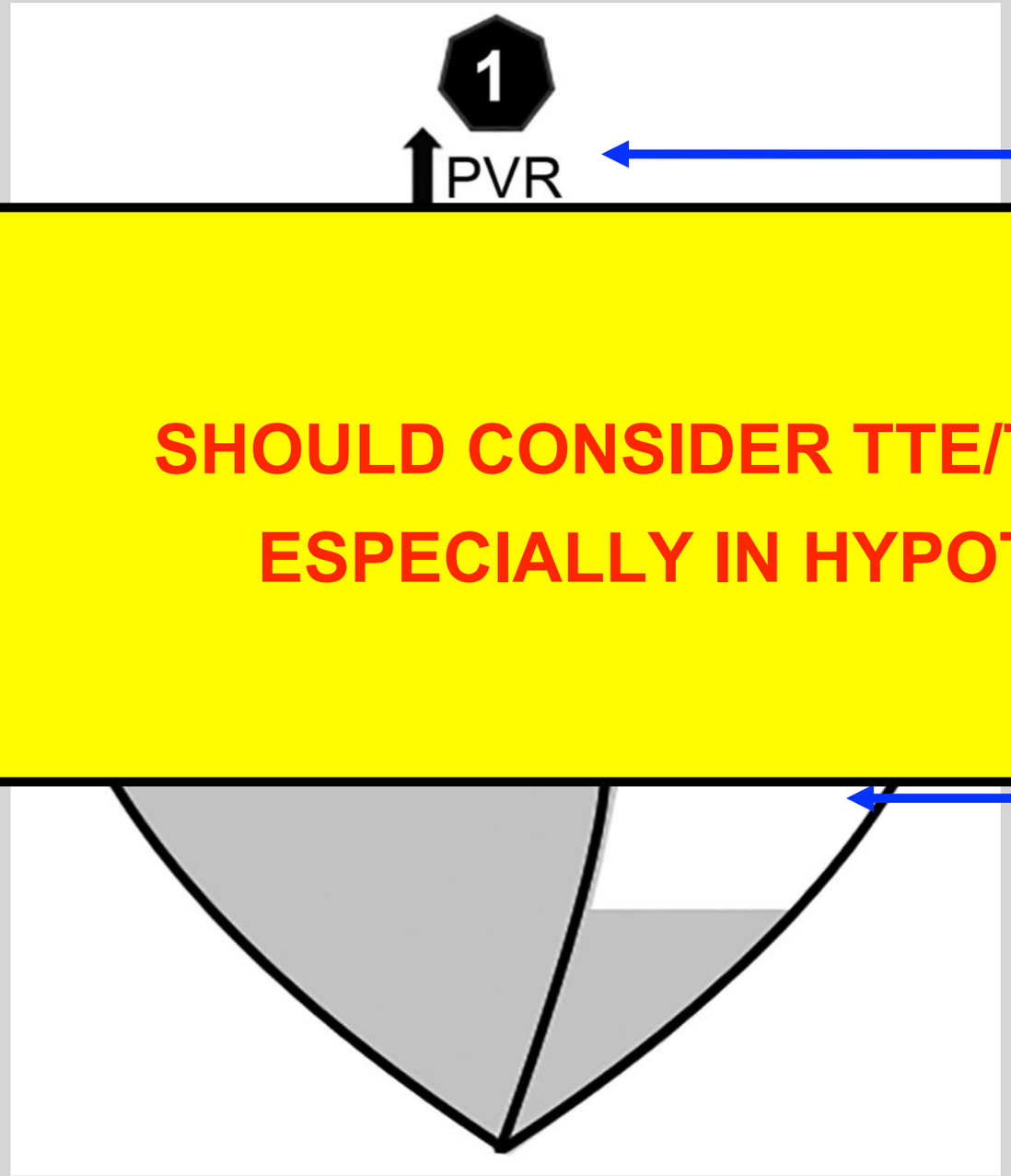
CARDIOPULMONARY INTERACTIONS



Delivering oxygenated blood to the pulmonary

SHOULD CONSIDER TTE/TEE PRIOR TO ECMO - ESPECIALLY IN HYPOTENSIVE PATIENTS

Relieving RV strain improves LV filling, delivering oxygenated blood to the coronaries can improve LV function

Verhoeff K, Mitchell JR. Cardiopulmonary physiology: why the heart and lungs are inextricably linked. *Adv Physiol Educ*. 2017;41(3):348-353. doi:10.1152/advan.00190.2016.

SHOULD I CONSIDER ECMO?

Indications and outcomes of extracorporeal life support in trauma patients

Justyna Swol, MD, Daniel Brodie, MD, Lena Napolitano, MD, Pauline K. Park, MD, Ravi Thiagarajan, MD, Ryan P. Barbaro, MD, Roberto Lorusso, MD, PhD, David McMullan, MD, Nicholas Cavarocchi, MD, Ali Ait Hssain, MD, Peter Rycus, MPH, David Zonies, MD, MPH, *and* **for the Extracorporeal Life Support Organization (ELSO)**, *Portland, Oregon*

Two hundred seventy-nine trauma patients were identified (0.92% of 30,273 adult ECLS patients). Extracorporeal life support increased significantly in the last 5 years (173 in 2011–2016, 62%) compared with 106 in the prior 18 years. Trauma patients were predominantly male (78%), with a mean age of 34.8 ± 15.4 years (range, 16–88 years). Thoracic injury was the most common diagnosis; acute respiratory distress syndrome was the most common indication. Extracorporeal life support was venovenous for respiratory failure (89%), VA for cardiac failure (7%), and VA for ECLS-assisted cardiopulmonary resuscitation (CPR) (E-CPR) (4%). Extracorporeal life support duration was 8.8 ± 9.5 days (longest 83 days), and was longer for respiratory support (9.3 ± 9.3 days) vs. cardiac support (4.1 ± 4.5 days) and E-CPR (6.5 ± 16.8 days). Overall survival from ECLS was 70% and survival to hospital discharge was 61% in the total cohort (63% respiratory, 50% cardiac, 25% E-CPR), similar to survival rates in other ELSO registry cohorts. More than 80% of patients had a reported complication during ECLS support. The most common complication was cardiovascular (51%) followed by a bleeding complication (29%). Multiple organ failure was the most common cause of death (15.4%). Data from the largest registry of critically ill trauma patients receiving ECLS support demonstrates reasonable survival. With growing experience and improved safety profile, trauma should not be considered a contraindication for ECLS. Further analysis of the ELSO registry regarding trauma-specific risk factors and ECLS-specific practices may identify best candidates and improve trauma ECLS outcomes. (*J Trauma Acute Care Surg.* 2018;84: 831–837. Copyright © 2018 American Association for the Surgery of Trauma. All rights reserved.)

Swol J, Brodie D, Napolitano L, et al. Indications and outcomes of extracorporeal life support in trauma patients. *J Trauma Acute Care*. 2018;84(6):831-837. doi:10.1097/TA.0000000000001895.

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A[illegible] for [illegible]gon

Mostly male (79%), ages 16-88 (mean 34)

VV (89%) mean length 9.3 days, survival 61%

VA (7%) mean length 4.1 days, survival 51%

ECPR (4%) 6.5 days, survival 25%

Two hundred seventy-ni[illegible]al life support increased significantly in the last [illegible] patients were predominantly male (78%), wi[illegible]ost common diagnosis; acute respiratory distres[illegible]venous for respiratory failure (89%), VA for [illegible](CPR) (E-CPR) (4%). Extracorporeal life sup[illegible]upport (9.3 ± 9.3 days) vs. cardiac support (4.1[illegible]nd survival to hospital discharge was 61% in the total cohort (63% respiratory, 50% cardiac, 25% E-CPR), similar to survival rates in other ELSO registry cohorts. More than 80% of patients had a reported complication during ECLS support. The most common complication was cardiovascular (51%) followed by a bleeding complication (29%). Multiple organ failure was the most common cause of death (15.4%). Data from the largest registry of critically ill trauma patients receiving ECLS support demonstrates reasonable survival. With growing experience and improved safety profile, trauma should not be considered a contraindication for ECLS. Further analysis of the ELSO registry regarding trauma-specific risk factors and ECLS-specific practices may identify best candidates and improve trauma ECLS outcomes. (*J Trauma Acute Care Surg.* 2018;84: 831–837. Copyright © 2018 American Association for the Surgery of Trauma. All rights reserved.)

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Use of extracorporeal membrane oxygenation in severe traumatic lung injury with respiratory failure

Wu S-C, Chen WT-L, Lin H-H, et al. Use of extracorporeal membrane oxygenation in severe traumatic lung injury with respiratory failure. *Am J Emerg Med*. 2015;33(5):658-662. doi:10.1016/j.ajem.2015.02.007.

Extracorporeal membrane oxygenation for adult respiratory distress syndrome in trauma patients: A case series and systematic literature review

Robba C, Ortu A, Bilotta F, et al. Extracorporeal membrane oxygenation for adult respiratory distress syndrome in trauma patients: A case series and systematic literature review. *J Trauma Acute Care*. 2017;82(1):165-173. doi:10.1097/TA.0000000000001276.

Extracorporeal membrane oxygenation after traumatic injury

Ahmad SB, Menaker J, Kufera J, O'Connor J, Scalea TM, Stein DM. Extracorporeal membrane oxygenation after traumatic injury. *J Trauma Acute Care*. 2017;82(3):587-591. doi:10.1097/TA.0000000000001352.

Predictive Survival Factors of the Traumatically Injured on Venovenous Extracorporeal Membrane Oxygenation: A Bayesian Model

Huang JE, Holland SR, Patrick J, Piper LC, Sams VG. Predictive Survival Factors of the Traumatically Injured on Venovenous Extracorporeal Membrane Oxygenation: A Bayesian Model. *J Trauma Acute Care*. August 2019. doi:10.1097/TA.0000000000002457.

Extracorporeal life support in trauma: Worth the risks? A systematic review of published series

Bedeir K, Seethala R, Kelly E. Extracorporeal life support in trauma: Worth the risks? A systematic review of published series. *J Trauma Acute Care*. 2017;82(2):400-406. doi:10.1097/TA.0000000000001292.

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Extracorporeal membrane oxygenation for adult respiratory

Robba C, Ortu A, Bilotta s: A case series and syste .

Extra njury

Ahmad SB, Menaker J Trauma Acute

Nothing explicit about trauma patients that would exclude them from consideration for ECMO

In certain patients, risk may outweigh reward

Thoughtful consideration to ECMO consideration is appropriate

Huang JE, Holland SR, Patrick J, Piper LC, Sams VG. Predictive Survival Factors of the Traumatically Injured on Venovenous Extracorporeal Membrane Oxygenation: A Bayesian Model. *J Trauma Acute Care*. August 2019. doi:10.1097/TA.0000000000002457.

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Predictors of hospital mortality in adult trauma patients receiving extracorporeal membrane oxygenation for advanced life support: a retrospective cohort study

Meng-Yu Wu[1,5,6*], Pin-Li Chou[2], Tzu-I Wu[3,4] and Pyng-Jing Lin[1]

Conclusions: The severity of trauma and the type of cardiopulmonary dysfunction significantly affected the outcomes of ECMO used for sustaining patients with post-traumatic cardiopulmonary dysfunction. Hemorrhage on ECMO remained a concern while the device was required soon after trauma, although a heparin-minimized protocol was adopted.

Endpoint	Predictor	β coefficient	Odds Ratio (95% CI)	*p* value
[a]Hospital Death	ISS > 35	1.905	6.716 (1.359–33.187)	0.019
	Shock/ Cardiac arrest	1.625	5.079 (1.012–25.499)	0.048
[b]Hemorrhage on ECMO	Pre-ECMO aPTT > 40 s	2.028	7.6 (1.609–35. 906)	0.01

Wu M-Y, Chou P-L, Wu T-I, Lin P-J. Predictors of hospital mortality in adult trauma patients receiving extracorporeal membrane oxygenation for advanced life support: a retrospective cohort study. *Scand J Trauma Resusc Emerg Med*. 2018;26(1):14–12. doi:10.1186/s13049-018-0481-6.

CONSIDERATIONS IN TRAUMA

- Alternate cannulation strategies
- Anticoagulation/bleeding
- TBI
- Social support/consent
- Distracting injuries
- Need for additional surgery/imaging = transport

CONSIDERATIONS IN TRAUMA

- **Alternate cannulation strategies**
- **Anticoagulation/bleeding**
- **TBI**
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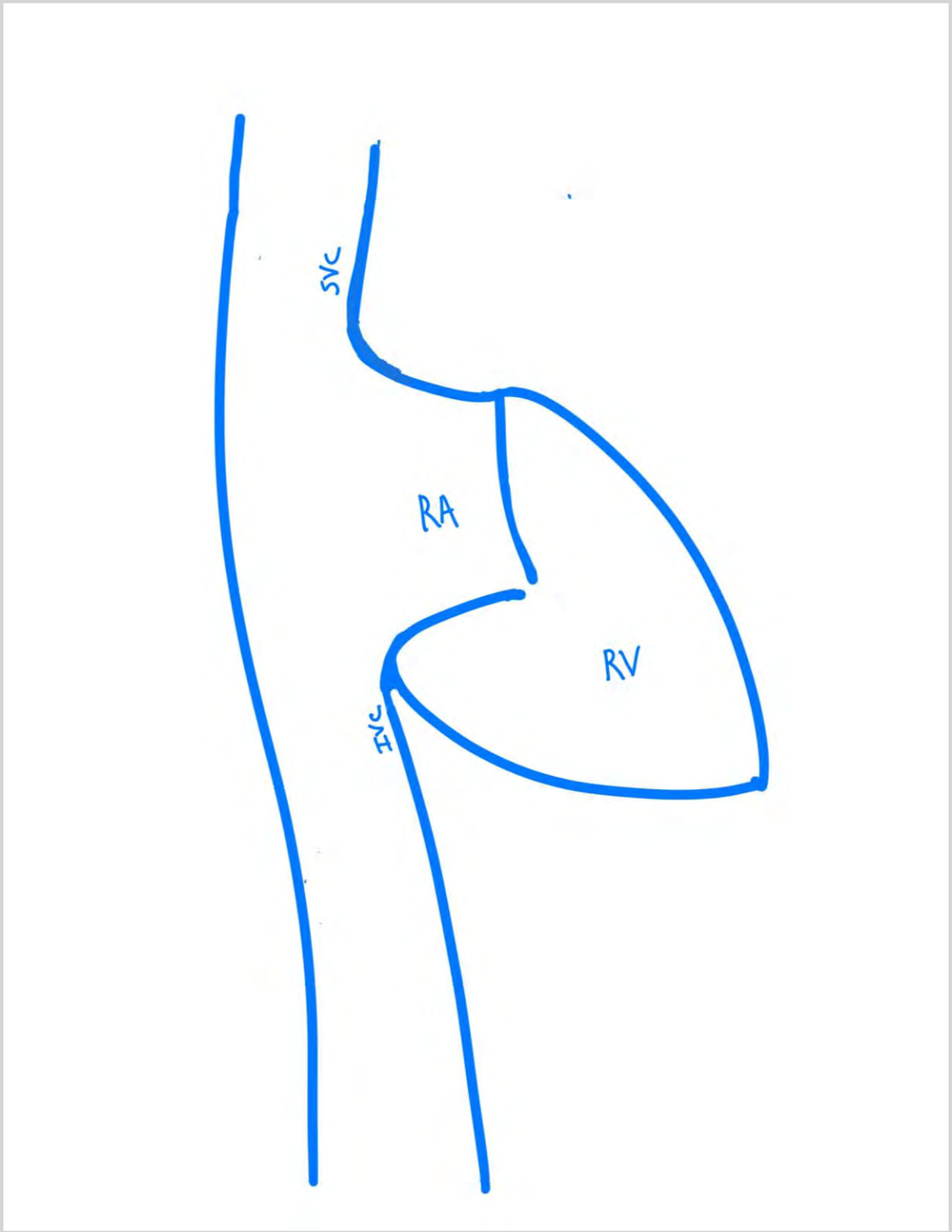
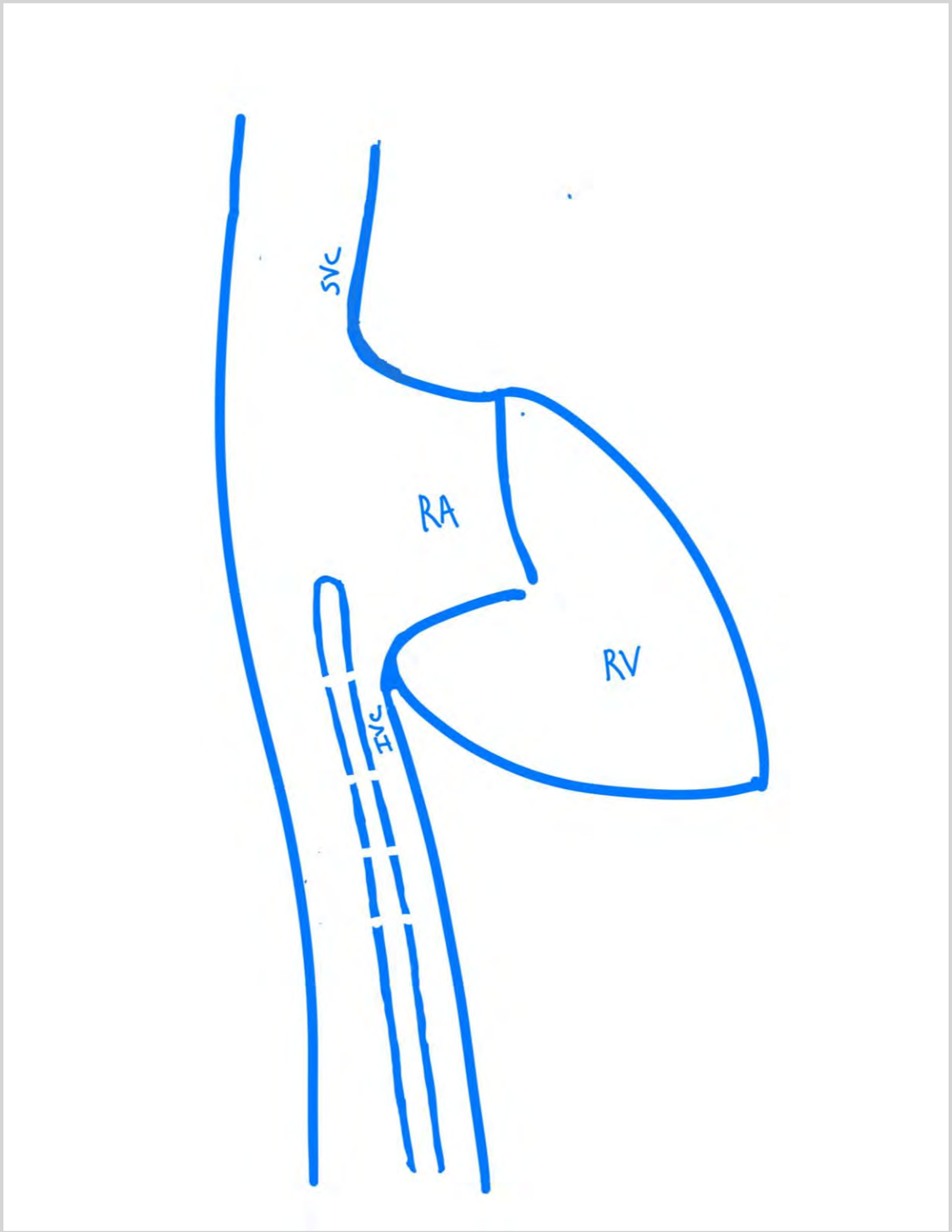
EXAMPLE VV ECMO CANNULATION



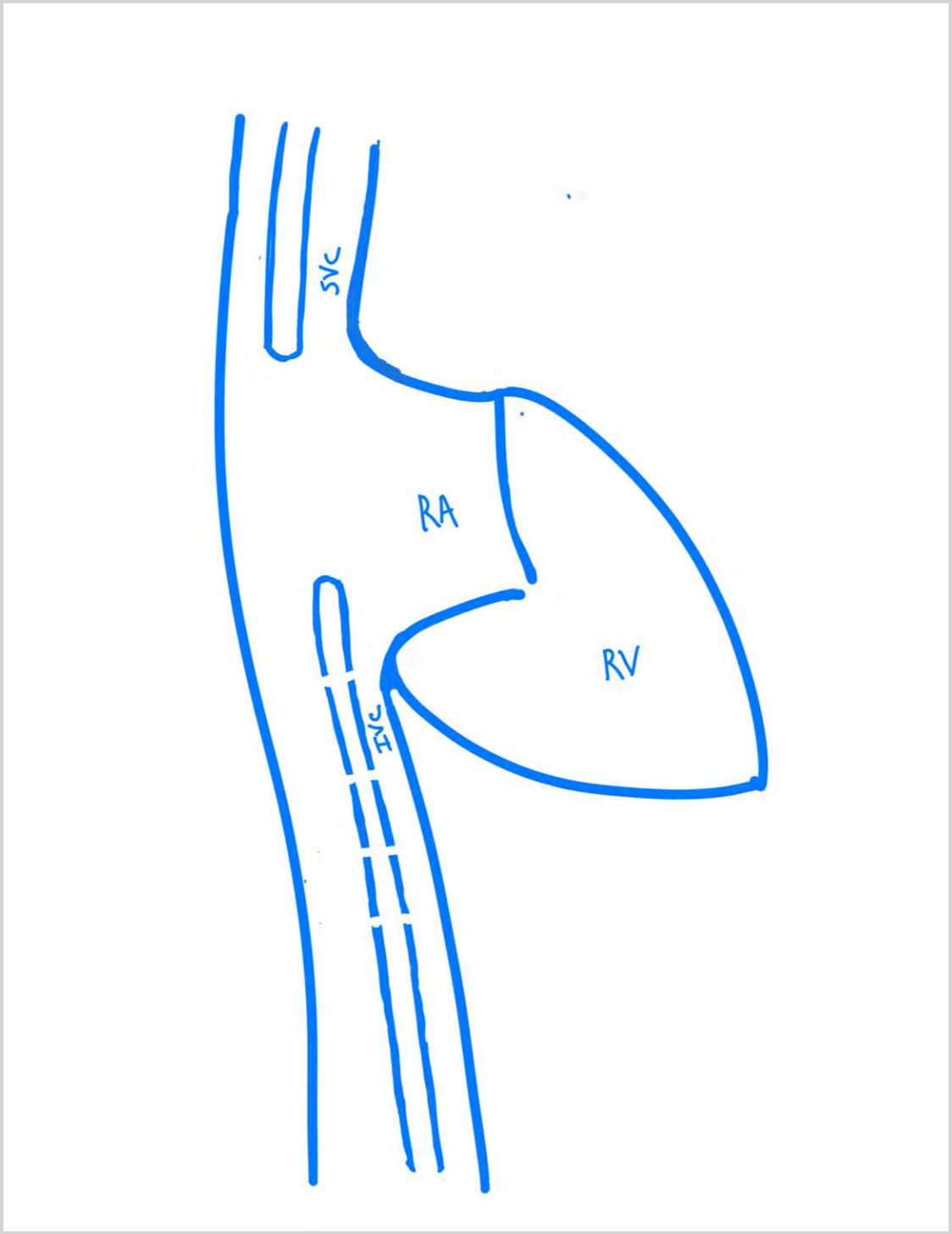
EXAMPLE VV ECMO CANNULATION

Large bore (21-29 Fr) venous cannula, inserted to ~40 cm via femoral vein



EXAMPLE VV ECMO CANNULATION

Smaller (16-23 Fr) “arterial” cannula, inserted to ~15 cm via right jugular vein



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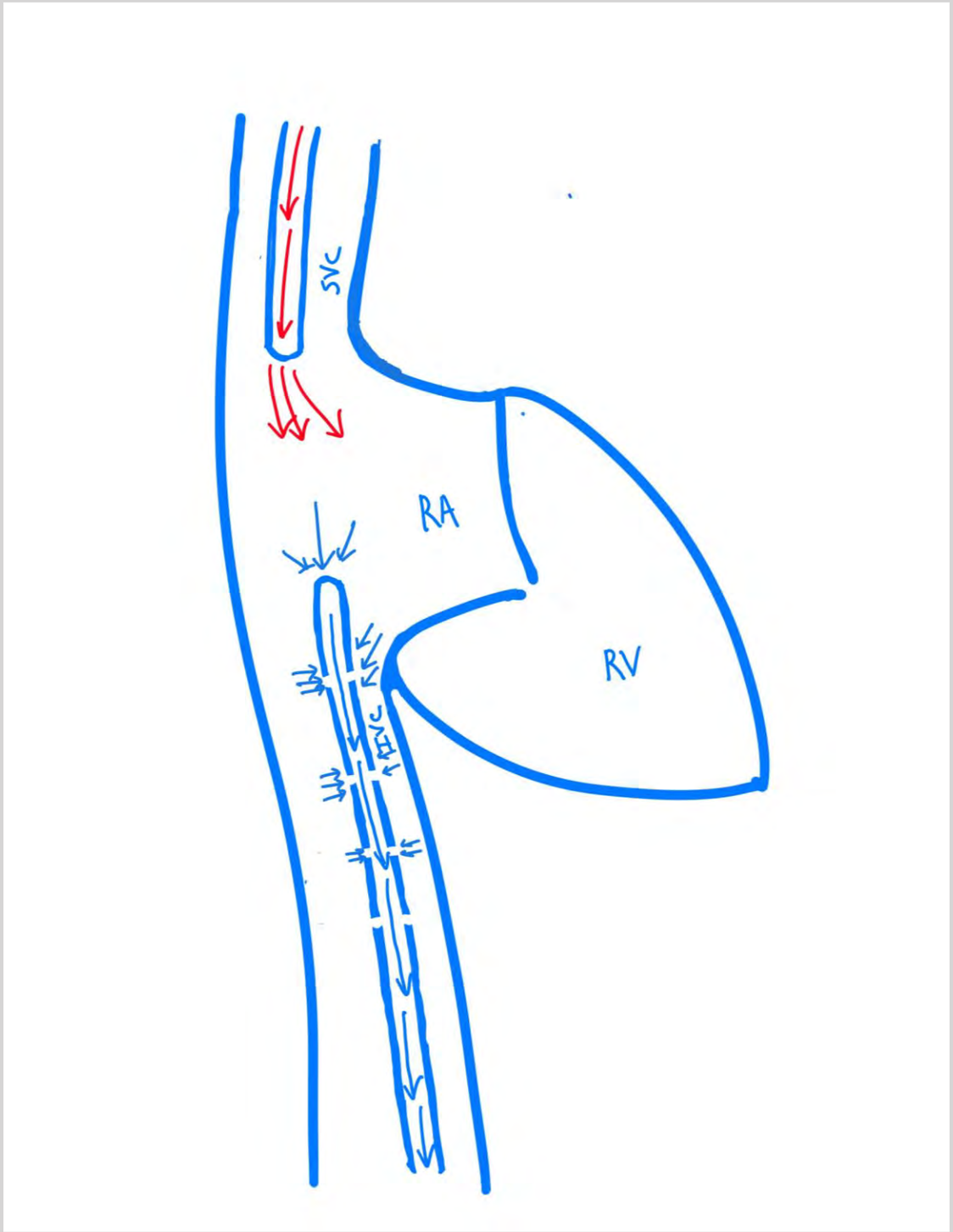
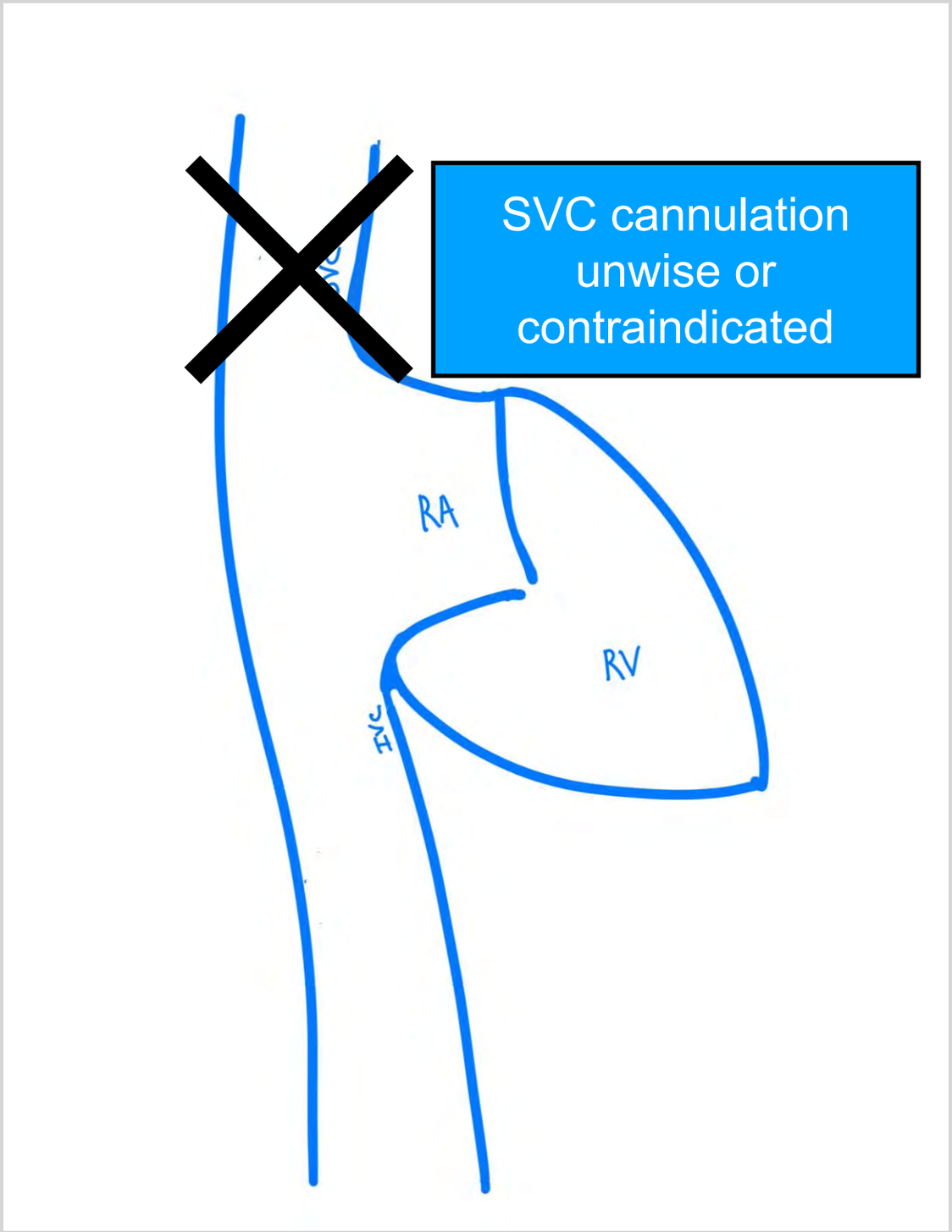


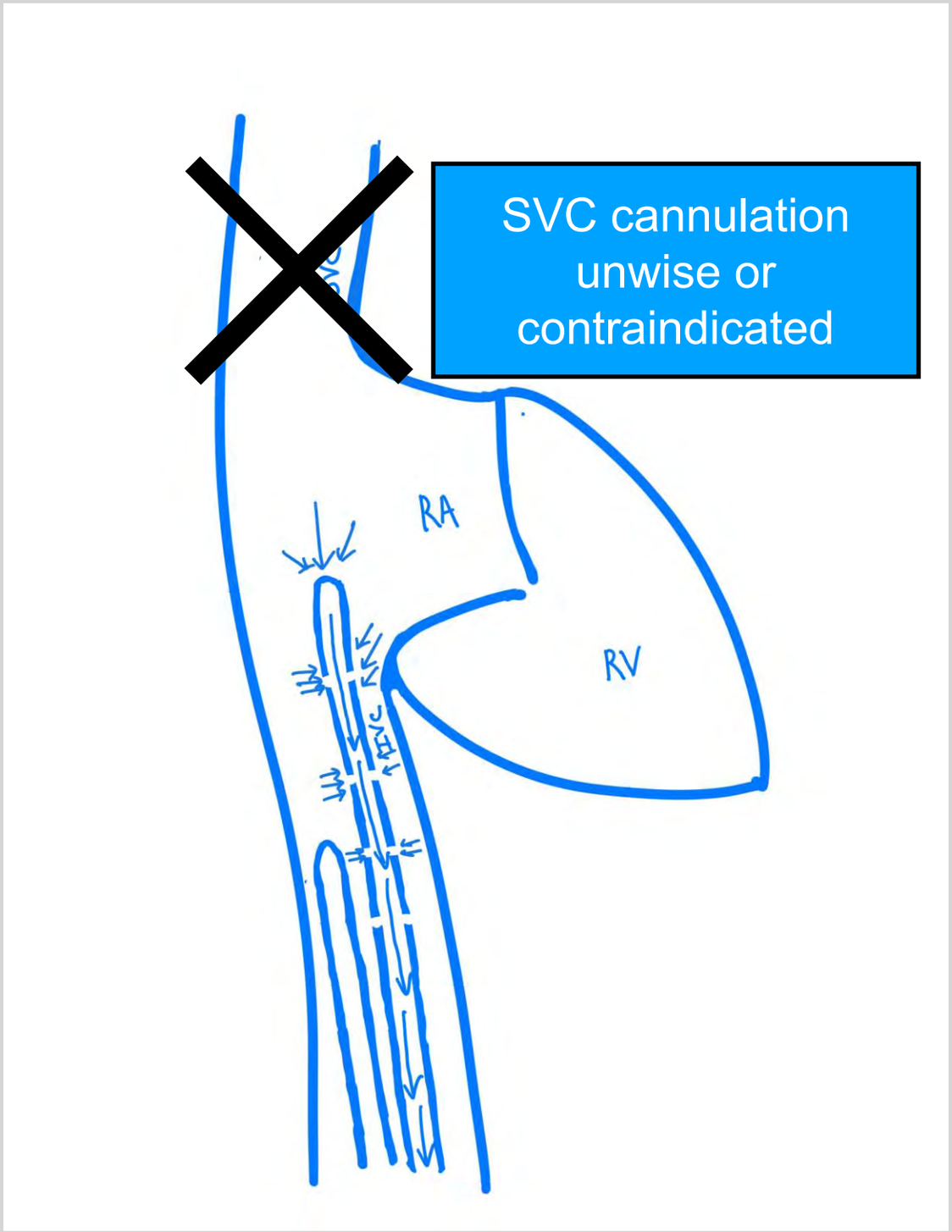
Drainage of deoxygenated blood and return of oxygenated blood

OTHER OPTIONS?



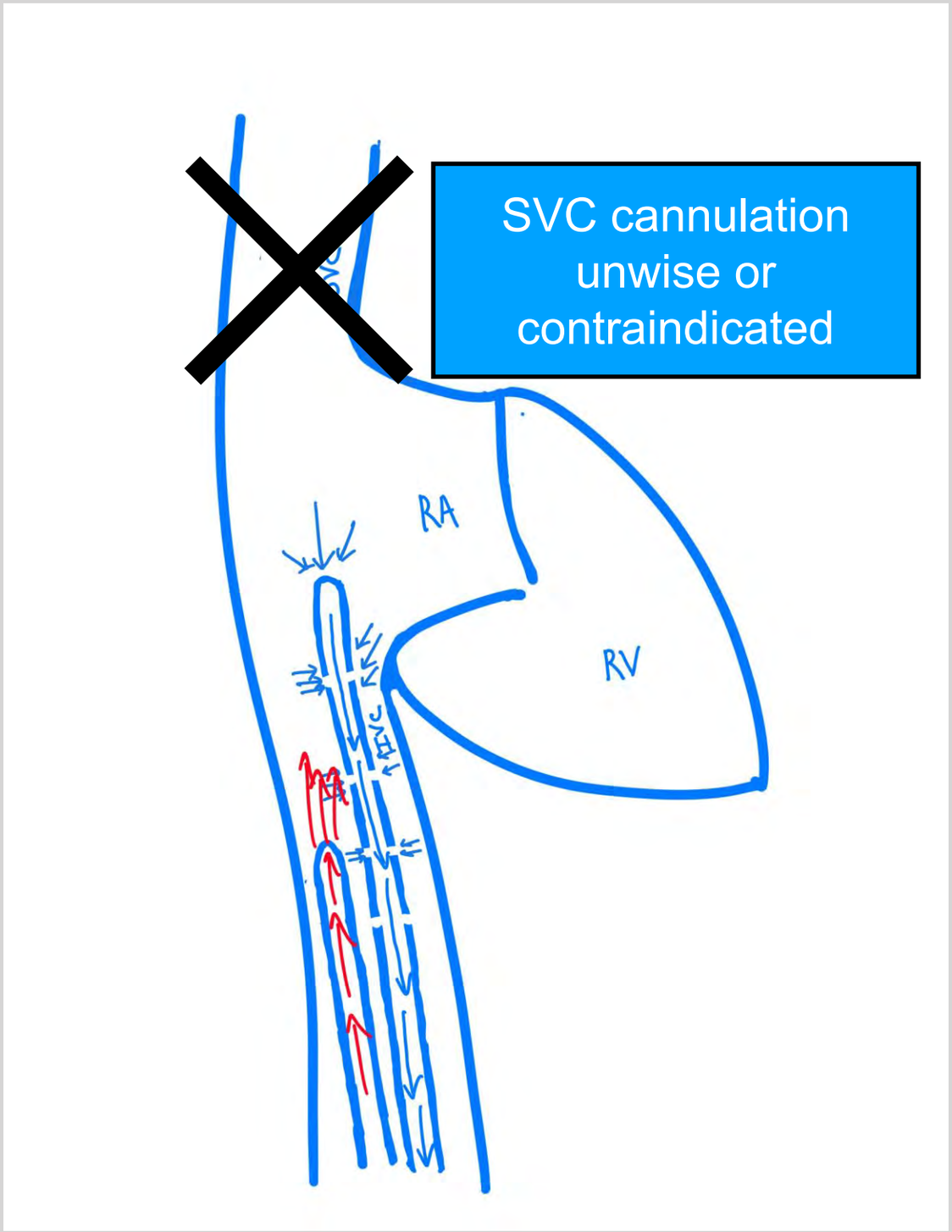
BIFEMORAL VV ECMO CANNULATION

Smaller (16-23 Fr) “arterial” cannula, inserted to ~25 cm via other femoral vein

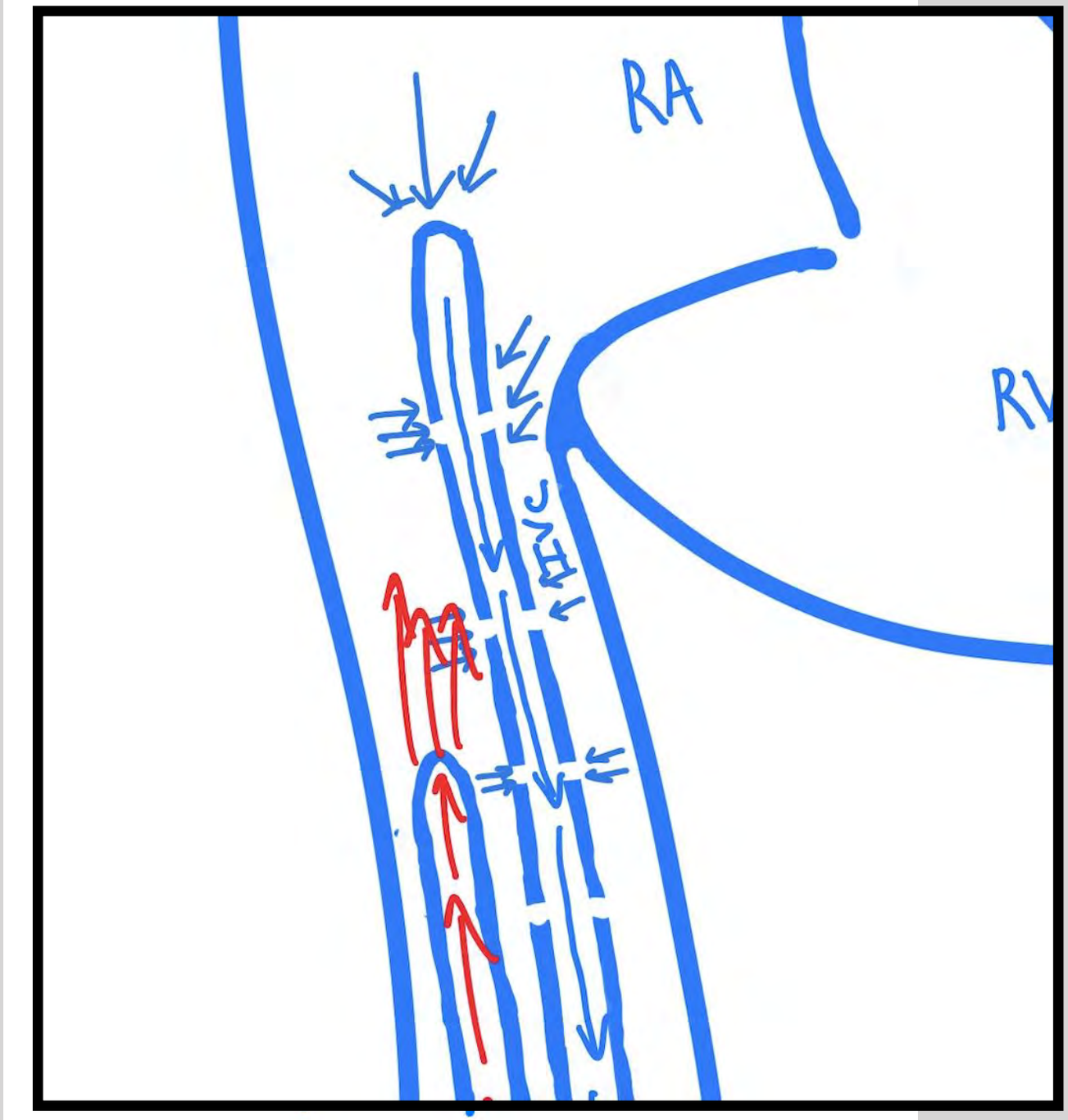


BIFEMORAL VV ECMO CANNULATION

Drainage of deoxygenated blood and return of oxygenated blood



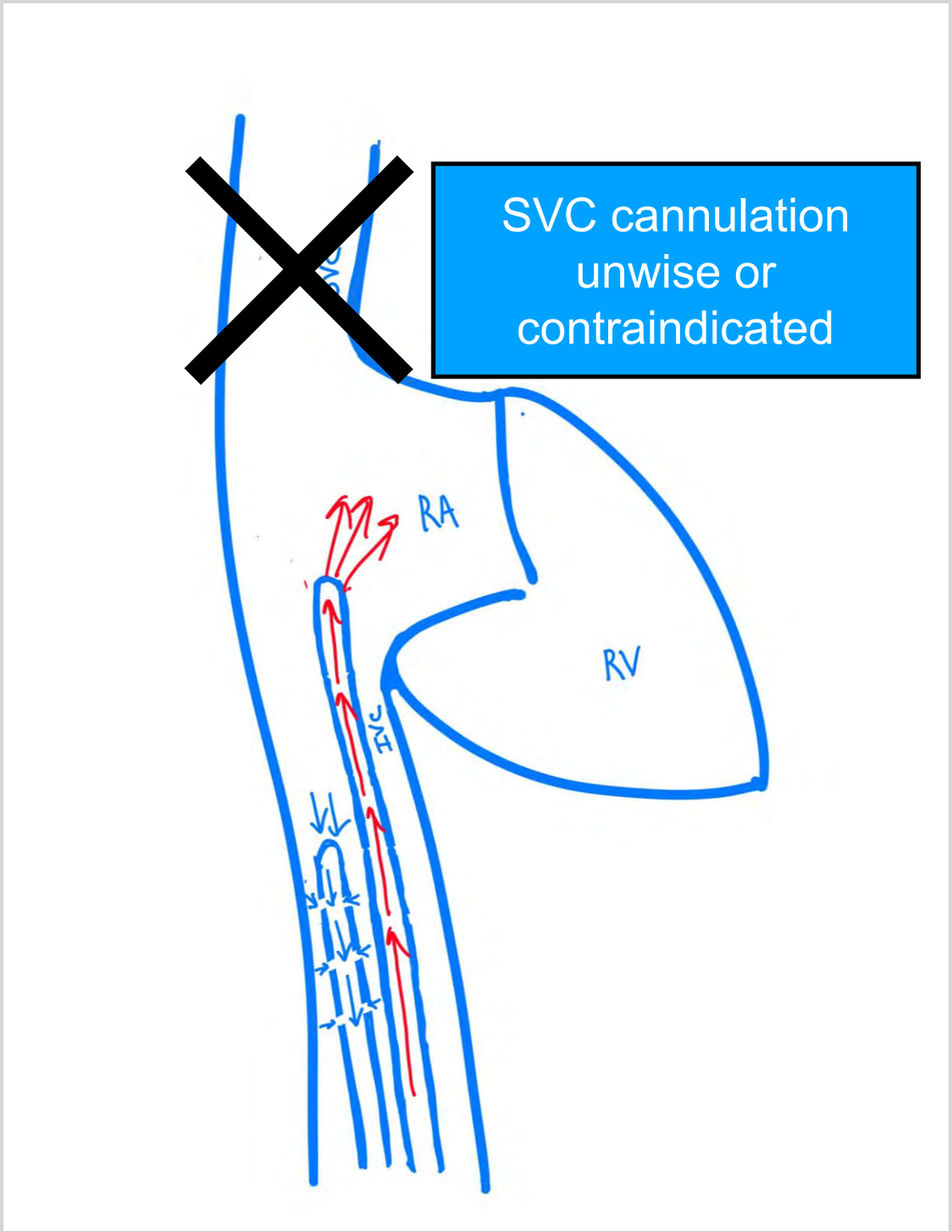
BIFEMORAL VV ECMO CANNULATION



Recirculation = worse hypoxia

Side note: all patients may remain hypoxemic to some degree (i.e. SpO2 ~85%), possibly even worse than pre-ECMO; however, the ability to rest the lungs may take precedent

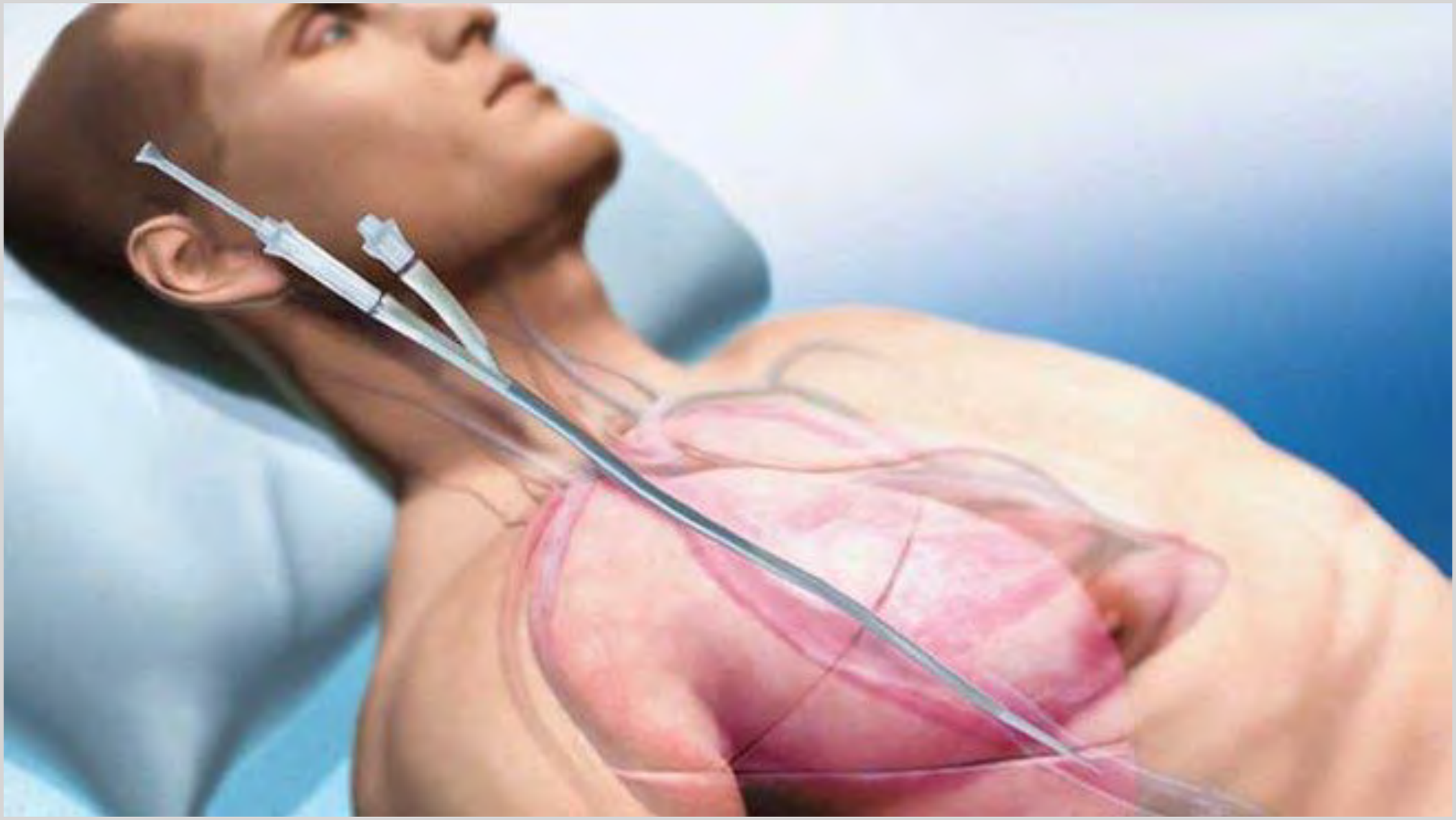
BIFEMORAL VV ECMO CANNULATION



Swapping the cannula configuration, placing the return closer to the RA can lessen recirculation

NEEDS TO BE PLANNED FOR - VERY DIFFICULT TO SWITCH TO THIS SETUP

DUAL-LUMEN VV ECMO CANNULATION



VV ECMO CANNULATION

Variables	Femoro-femoral	Femoro-jugular	Dual lumen cannula
Speed of insertion	Fastest	Moderate	Moderate
Preparation areas	One	Two	One
Recirculation risk	Potentially high	Potentially moderate	Potentially low, but high when poor position
Blood flow, L/min	2–6	2–7	3–5
Insertion complexity	Simple	Moderate	Potentially complex
Imaging requirements	Vascular/TTE	Vascular/TTE +/– TOE	Vascular/TOE/II
Patient mobilization potential	Complex	Complex	Less complex
Infection risk potential	High	High	Low
Risk of air embolism during removal	Low	Moderate*	High*

*, especially if spontaneously breathing. TTE, transthoracic echocardiogram; TOE, transoesophageal echocardiogram; II, image intensifier.

Bi-femoral cannulation is potentially the fastest, with fewer imaging requirements

Major potential problems: recirculation, mobility limited, infection risk, DVT

Burrell AJC, Ihle JF, Pellegrino VA, Sheldrake J, Nixon PT. Cannulation technique: femoro-femoral. *J Thorac Dis*. 2018;10(Suppl 5):S616-S623. doi:10.21037/jtd.2018.03.83.

BLEEDING/ANTICOAGULATION

- Why do we need anticoagulation for ECMO patients?

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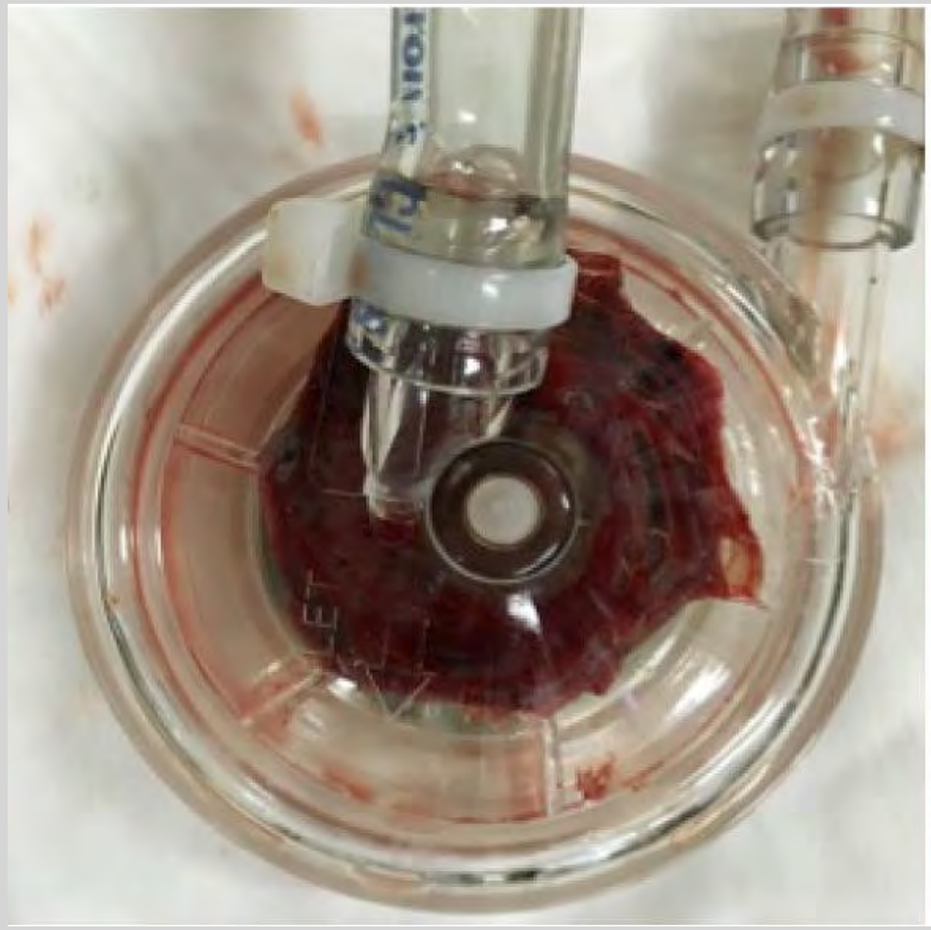
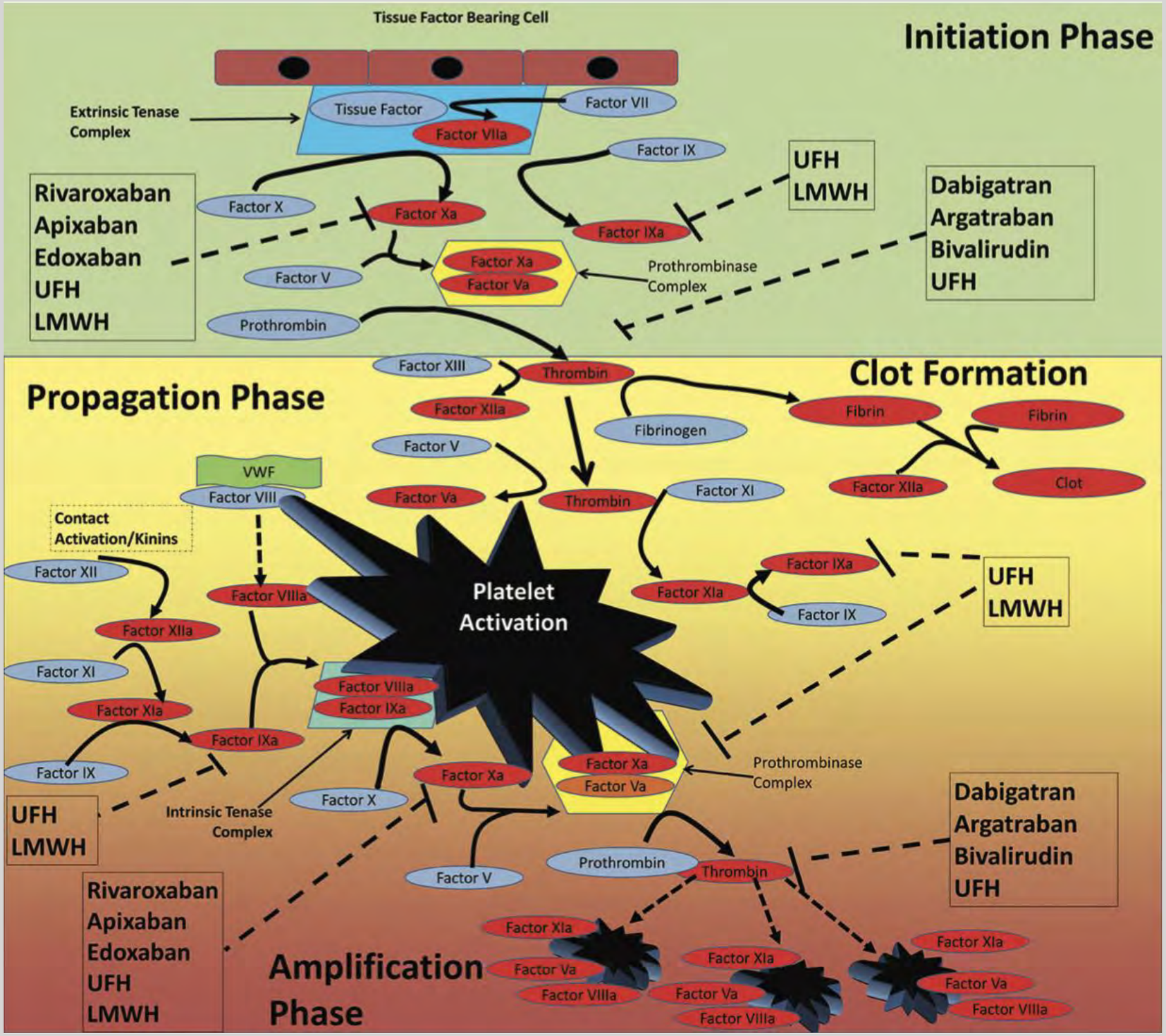


https://www.semanticscholar.org/paper/Soluble-fibrin-is-a-useful-marker-for-predicting-of-Hoshino-Muranishi/260ecee00cb9d75e6f2e6cf042fdae265cdd4ca9



- Inflammatory conditions
- Presence of foreign surfaces
- Lower ECMO flows
- Duration of support
- Size of cannulae
- Resuscitation

Lots of opportunity for clot to form (also therapeutic targets)

Maul TM, Massicotte MP, Wearden PD. ECMO Biocompatibility: Surface Coatings, Anticoagulation, and Coagulation Monitoring. In: *Extracorporeal Membrane Oxygenation: Advances in Therapy*. InTech; 2016:1-37. doi:10.5772/63888.

BLEEDING/ANTICOAGULATION

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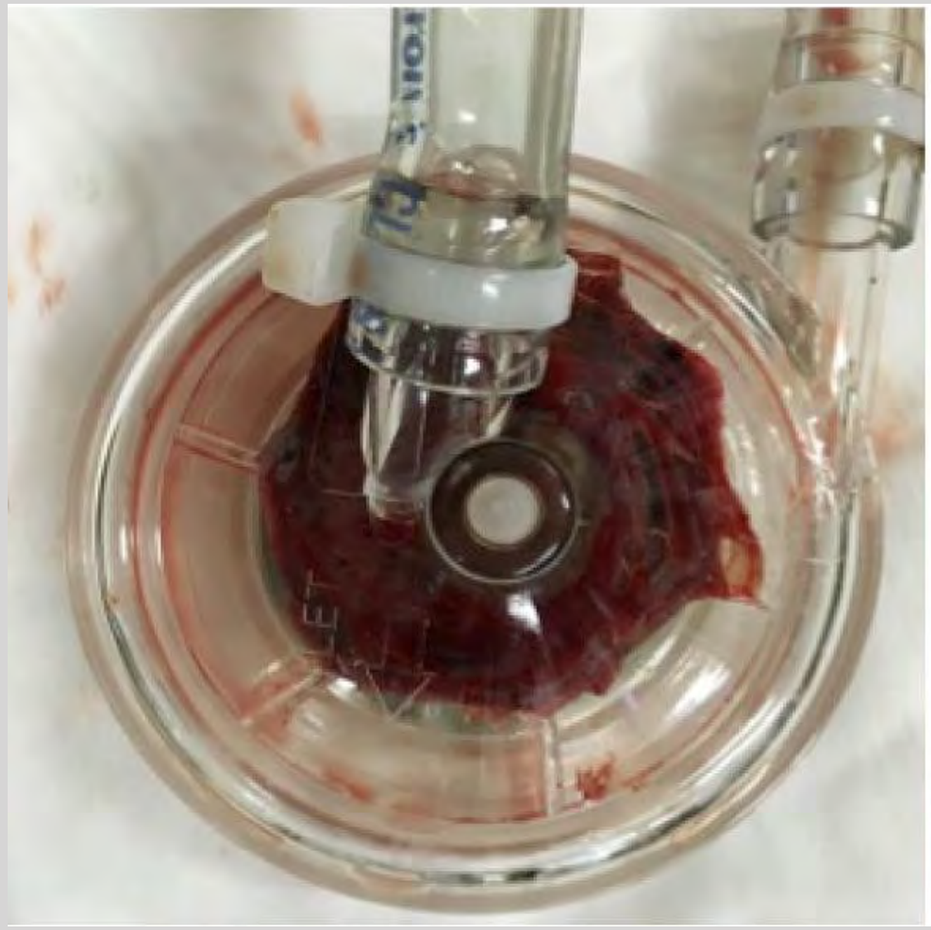

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- Can we avoid anticoagulation in ECMO patients?

Venovenous Extracorporeal Membrane Oxygenation With Prophylactic Subcutaneous Anticoagulation Only: An Observational Study in More Than 60 Patients

*Kirsten Krueger, *Axel Schmutz, †Barbara Zieger, and *Johannes Kalbhenn

- Societal recommendations are to anticoagulate ECMO patients to ACT/PTT/Xa assay around 1.5-2.5 X normal
- Risks of inadequate anticoagulation include circuit and systemic thrombosis
- But unclear what the actual risks of NOT anticoagulating are
- **Case reports/series have suggested that VV ECMO can be safely provided without systemic anticoagulation**

Krueger K, Schmutz A, Zieger B, Kalbhenn J. Venovenous Extracorporeal Membrane Oxygenation With Prophylactic Subcutaneous Anticoagulation Only: An Observational Study in More Than 60 Patients. *Artif Organs*. 2017;41(2):186-192. doi:10.1111/aor.12737.

Venovenous Extracorporeal Membrane Oxygenation With Prophylactic Subcutaneous Anticoagulation Only: An Observational Study in More Than 60 Patients

Inability to fully anticoagulate should be strong contraindication to VA ECMO at this time

…but maybe only a relative contraindication to VV ECMO?

- Soc … ts to *A*

- Ris… systemic thrombosis

- But unclear what the actual risks of NOT anticoagulating are

- **Case reports/series have suggested that VV ECMO can be safely provided without systemic anticoagulation**

Krueger K, Schmutz A, Zieger B, Kalbhenn J. Venovenous Extracorporeal Membrane Oxygenation With Prophylactic Subcutaneous Anticoagulation Only: An Observational Study in More Than 60 Patients. *Artif Organs*. 2017;41(2):186-192. doi:10.1111/aor.12737.

BLEEDING/ANTICOAGULATION

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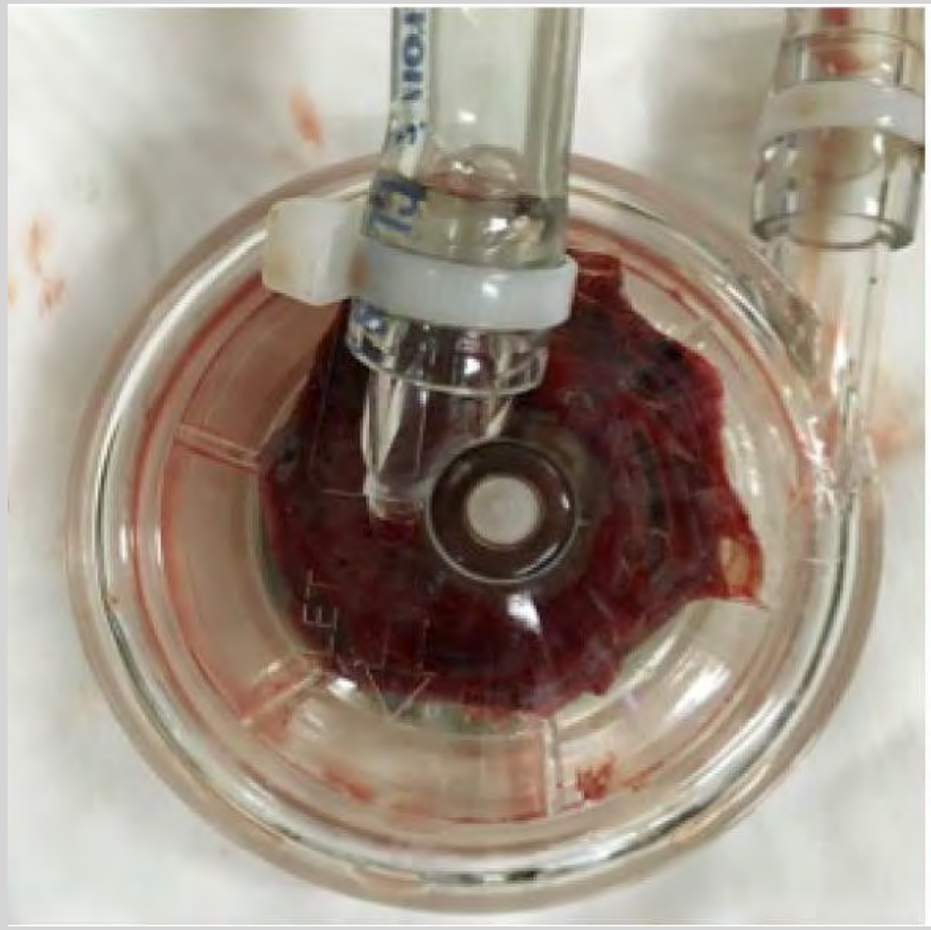

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- Can we avoid anticoagulation in ECMO patients?
  - **Maybe…**

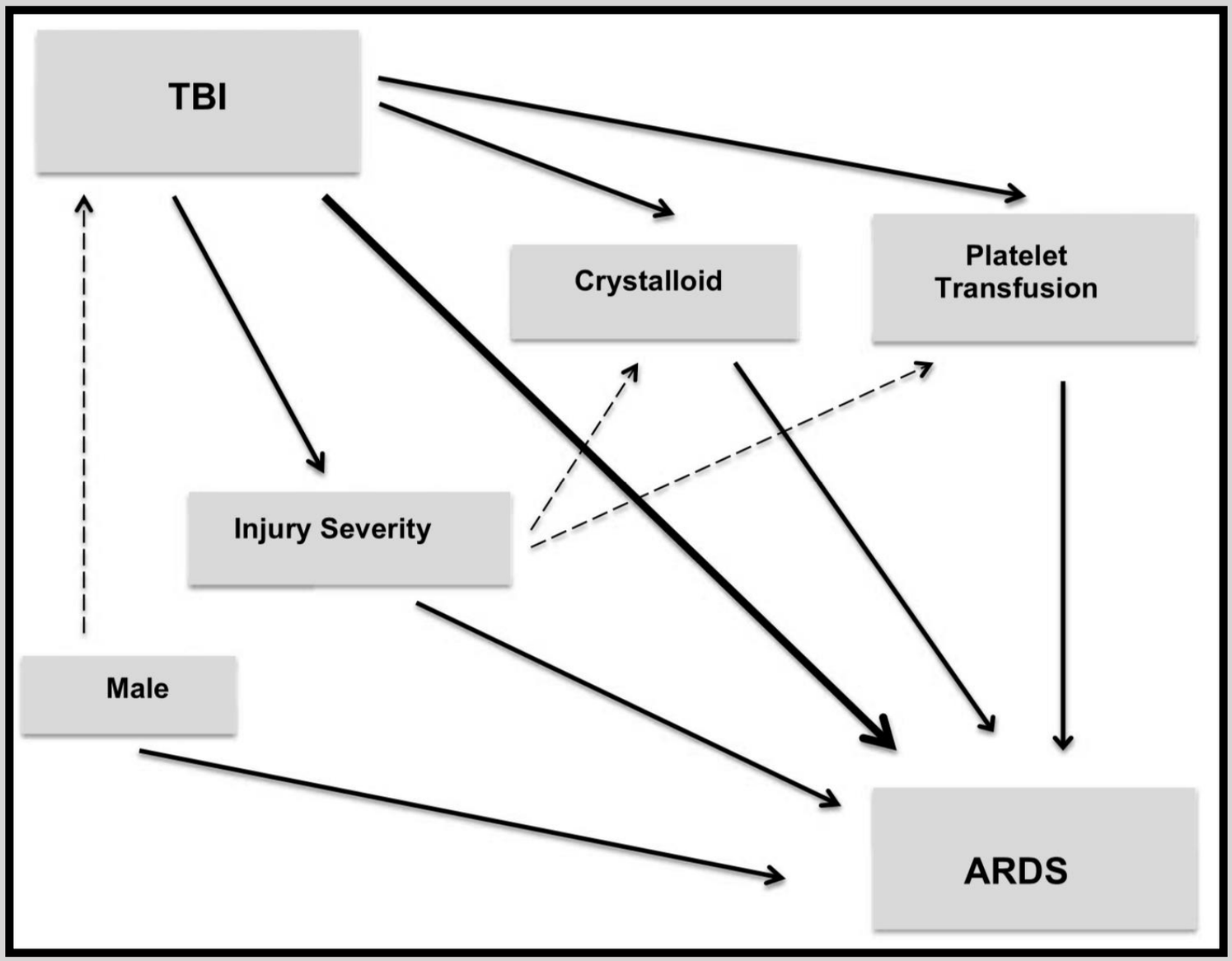
NEUROLOGIC INJURY IN TRAUMA

- Concussive/TBI
- Subdural hemorrhage
- Intraparynchemal hemorrhage
- Skull fracture
- Spinal cord injury
- Peripheral nerve injuries
- Others…

The acute respiratory distress syndrome following isolated severe traumatic brain injury

Carolyn M. Hendrickson, MD, MPH, Benjamin M. Howard, MD, MPH, Lucy Z. Kornblith, MD, Amanda S. Conroy, Mary F. Nelson, RN, MPA, Hanjing Zhuo, MD, MPH, Kathleen D. Liu, MD, PhD, Geoffrey T. Manley, MD, PhD, Michael A. Matthay, MD, Carolyn S. Calfee, MD, MAS, *and* **Mitchell J. Cohen, MD***, San Francisco, California*

Hypothetical pathway from TBI->ARDS



Hendrickson CM, Howard BM, Kornblith LZ, et al. The acute respiratory distress syndrome following isolated severe traumatic brain injury. *J Trauma Acute Care*. 2016;80(6):989-997. doi:10.1097/TA.0000000000000982.

NEUROLOGIC INJURY IN TRAUMA

Many of the facets of acute lung injury can directly impact the ability of the neurologic trauma to recover:

- High vent settings/PEEP
- Hypoxia/hypercarbia
- Acidosis
- RV strain + cerebral/hepatic congestion
- Hypotension/vasopressor use

- Others…

Neurologic trauma/TBI should not be considered absolute contraindication to ECMO

Incidence, Outcome, and Predictors of Intracranial Hemorrhage in Adult Patients on Extracorporeal Membrane Oxygenation: A Systematic and Narrative Review

Alexander Fletcher-Sandersjöö [1,2], Eric Peter Thelin [2,3], Jiri Bartek Jr. [1,2,4,5], Mikael Broman [6,7], Marko Sallisalmi [6], Adrian Elmi-Terander [1] and Bo-Michael Bellander [1,2]*

Summary of Main Findings

We conducted a systematic review of the incidence, outcome and predictors of ECMO associated ICH in adults. Twenty-five articles were included. We found an ICH-incidence between 1.8 and 21%. Developing an ICH was associated with a mortality of 32–100%, with a relative risk of mortality of 1.27–4.43 in patients that developed ICH as compared to those that did not. To the best of our knowledge, this is the first review of ICH in ECMO-treated adult patients and contributes findings that are important for patient management and future study design.

"…complicated balance between pro- and anticoagulatory demands"

Fletcher-Sandersjöö A, Thelin EP, Bartek J, et al. Incidence, Outcome, and Predictors of Intracranial Hemorrhage in Adult Patients on Extracorporeal Membrane Oxygenation: A Systematic and Narrative Review. *Front Neurol*. 2018;9:548. doi:10.3389/fneur.2018.00548.

Management of intracranial hemorrhage in adult patients on extracorporeal membrane oxygenation (ECMO): An observational cohort study

Alexander Fletcher-Sandersjöö[1,2]*, Eric Peter Thelin[2,3], Jiri Bartek, Jr.[1,2,4,5], Adrian Elmi-Terander[1], Mikael Broman[6,7], Bo-Michael Bellander[1,2]

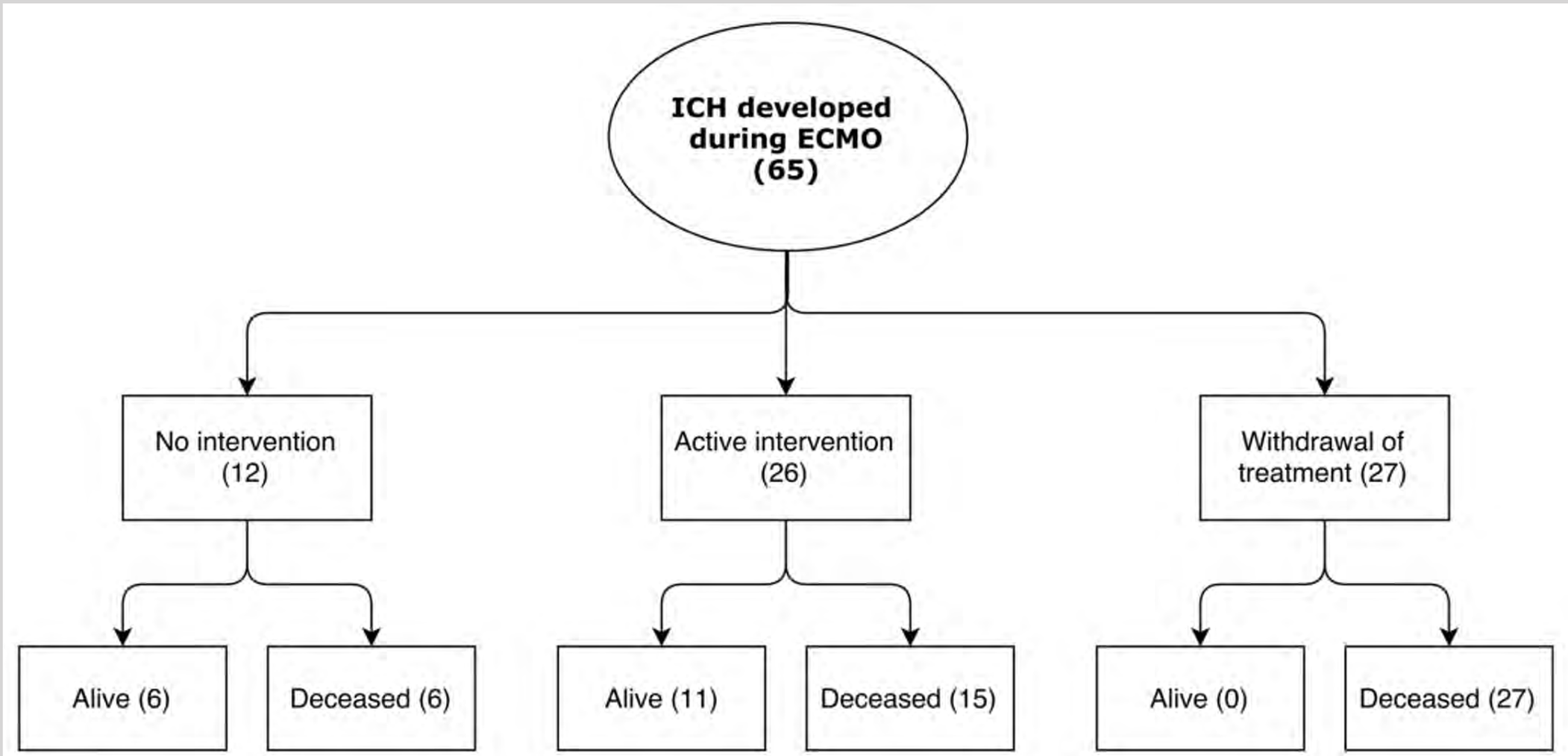


Fig 1. Patient management and outcome within 30 days of ICH diagnosis. Abbreviations: ICH = Intracranial hemorrhage; ECMO = Extracorporeal membrane oxygenation.

Fletcher-Sandersjöö A, Thelin EP, Bartek J, Elmi-Terander A, Broman M, Bellander B-M. Management of intracranial hemorrhage in adult patients on extracorporeal membrane oxygenation (ECMO): An observational cohort study. *PLoS ONE*. 2017;12(12):e0190365. doi:10.1371/journal.pone.0190365.

Management of intracranial hemorrhage in adult patients on extracorporeal membrane oxygenation (ECMO): An observational cohort study

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ICH on ECMO is not necessarily a "lost cause"

Maybe its okay to let non-catastrophic ICH evolve, especially if anticoagulation can be held

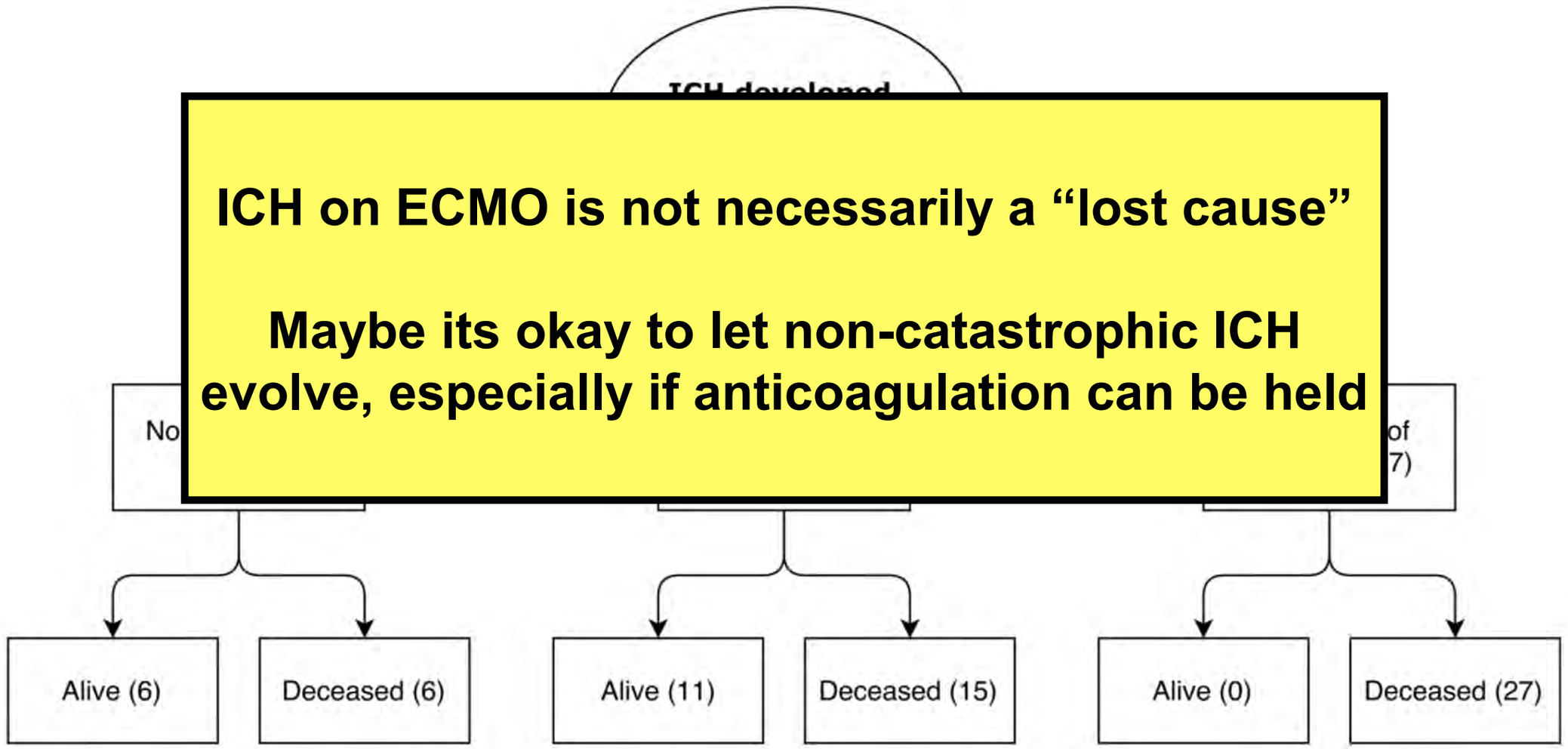


Fig 1. Patient management and outcome within 30 days of ICH diagnosis. Abbreviations: ICH = Intracranial hemorrhage; ECMO = Extracorporeal membrane oxygenation.

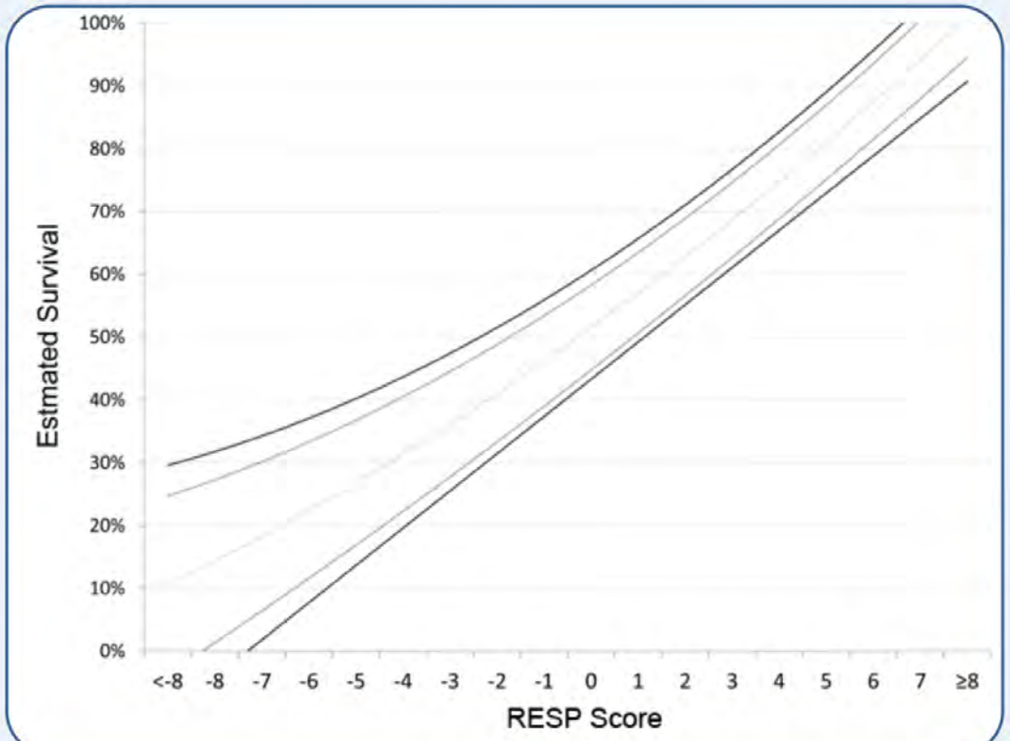
Fletcher-Sandersjöö A, Thelin EP, Bartek J, Elmi-Terander A, Broman M, Bellander B-M. Management of intracranial hemorrhage in adult patients on extracorporeal membrane oxygenation (ECMO): An observational cohort study. *PLoS ONE*. 2017;12(12):e0190365. doi:10.1371/journal.pone.0190365.

SURVIVAL PREDICTORS

The **RESP** Score

The RESP Score has been developed by **ELSO** and **The Department of Intensive Care at The Alfred Hospital, Melbourne**. It is designed to assist prediction of survival for adult patients undergoing Extra-Corporeal Membrane Oxygenation for respiratory failure. It should not be considered for patients who are not on ECMO or as substitute for clinical assessment.

For more information see:
Schmidt M, Bailey M, Sheldrake J, et al. Predicting Survival after ECMO for Severe Acute Respiratory Failure: the Respiratory ECMO Survival Prediction (RESP)-Score. Am J Respir Crit Care Med. 2014.



The patient's RESP Score is

0

Age (years:)

- 18-49
- 50-59
- ≥60

Immunocompromised No

Mechanical ventilation prior to initiation of ECMO

- <48 hours
- 48 hours - 7 days
- >7 days

Acute Respiratory diagnosis group

- Viral pneumonia
- Bacterial pneumonia
- Asthma
- Trauma/burn
- Aspiration pneumonitis
- Other acute respiratory diagnosis
- Non-respiratory and chronic respiratory diagnoses

Central nervous system dysfunction No

Acute associated (non-pulmonary) infection No

Neuro-muscular blockade before ECMO No

Nitric oxide use before ECMO No

Bicarbonate infusion before ECMO No

Cardiac arrest before ECMO No

$PaCO_2$ ≥75 mmHg / 10kpa No

Peak inspiratory pressure ≥42cmH_2O No

http://www.respscore.com/

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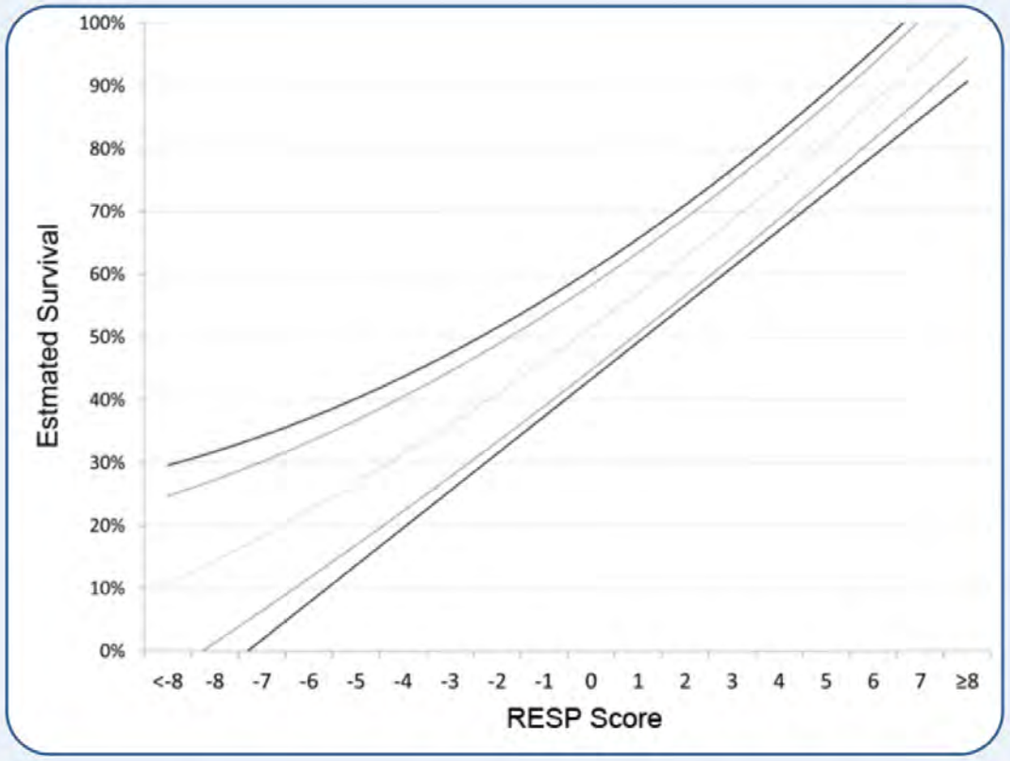

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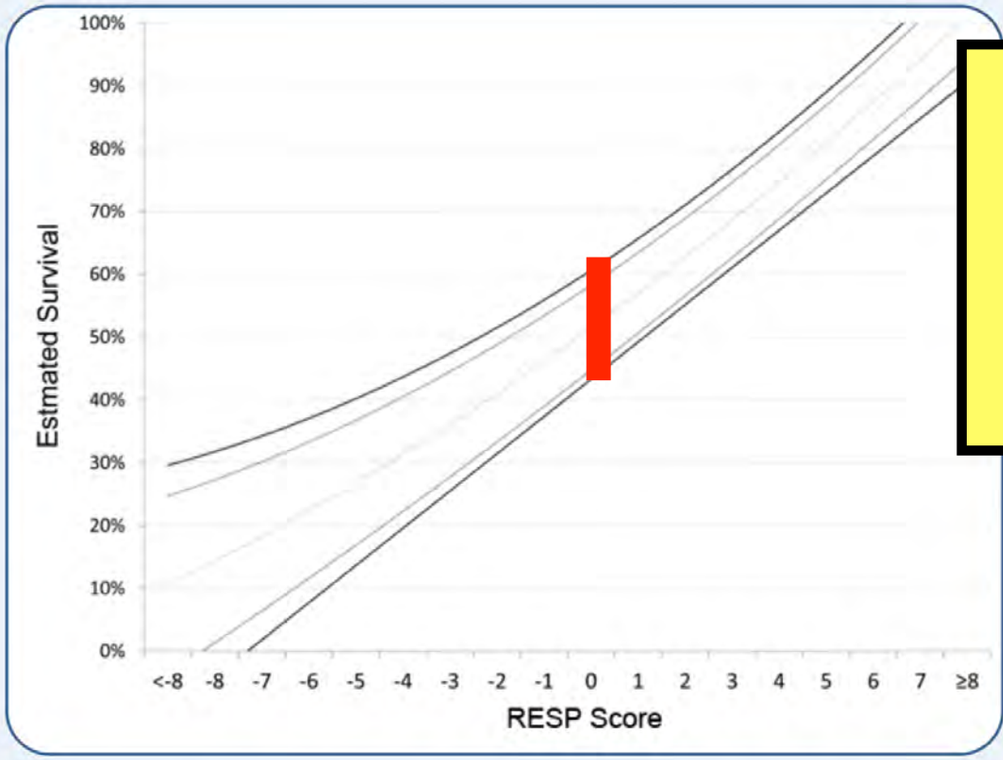

The patient's RESP Score is

0

Age (years:)

18-49
50-59
≥60

- **52 year old female patient**
- **bacterial pneumonia**
- **intubated 5 days**
- **NMB prior to ECMO**
- **paCO2 >75 mmHg**
- **PIP >42 cmH2O**

Central nervous system dysfunction
Acute associated (non-pulmonary) infection
Neuro-muscular blockade before ECMO
Nitric oxide use before ECMO
Bicarbonate infusion before ECMO
Cardiac arrest before ECMO

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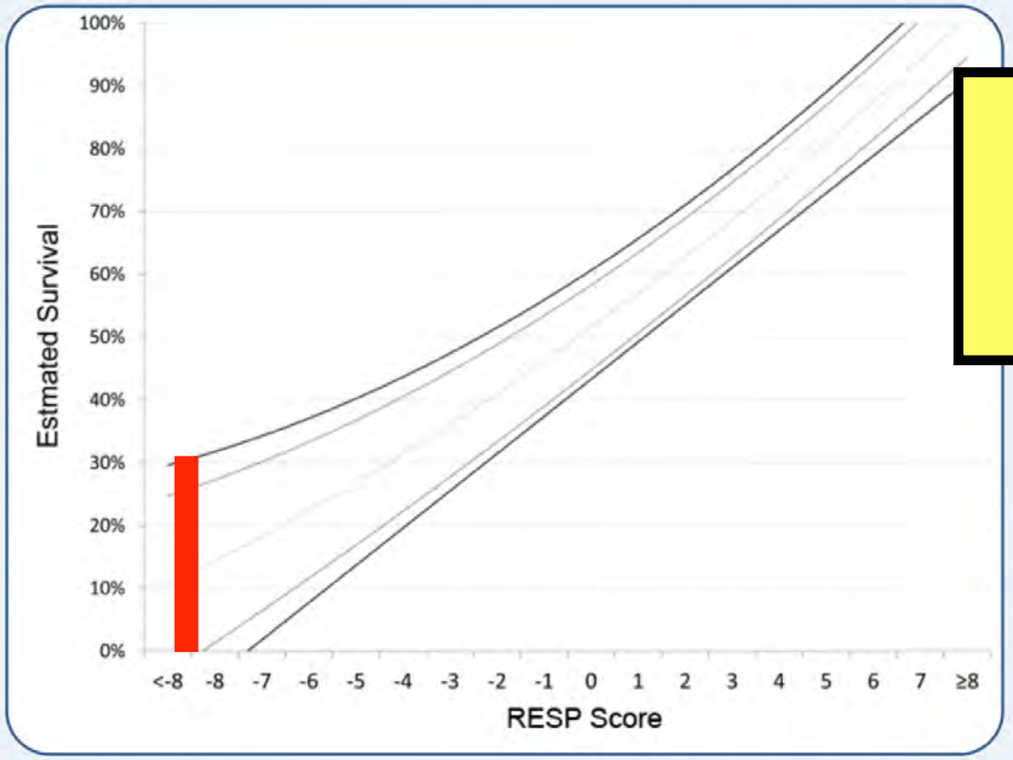

The patient's RESP Score is

0

Age (years:)

18-49
50-59
≥60

Immunocompromised

- 68 year old female
- Systemic sepsis with ARDS
- immunosuppressed 2/2 RA
- intubated >7 days

Aspiration pneumonitis
Other acute respiratory diagnosis
Non-respiratory and chronic respiratory diagnoses

Central nervous system dysfunction
Acute associated (non-pulmonary) infection
Neuro-muscular blockade before ECMO
Nitric oxide use before ECMO
Bicarbonate infusion before ECMO
Cardiac arrest before ECMO

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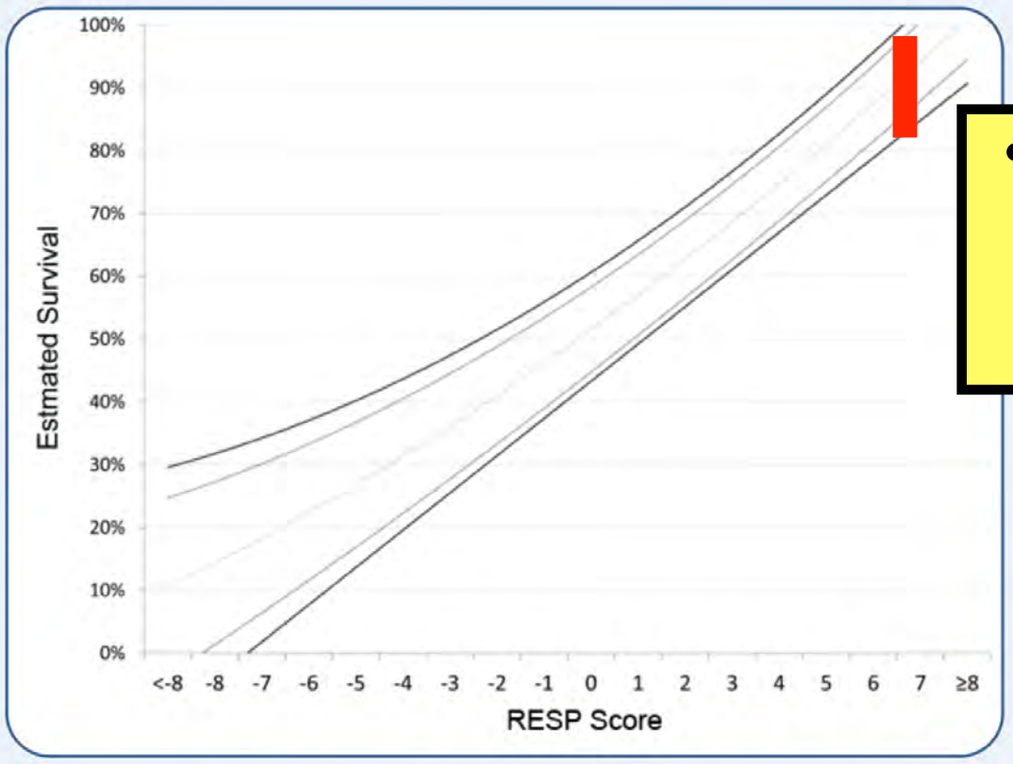

The patient's RESP Score is

0

Age (years:)

18-49
50-59
≥60

Immunocompromised

Other acute respiratory diagnosis
Non-respiratory and chronic respiratory diagnoses

Central nervous system dysfunction

Acute associated (non-pulmonary) infection

Neuro-muscular blockade before ECMO

Nitric oxide use before ECMO

Bicarbonate infusion before ECMO

Cardiac arrest before ECMO

- **25 year old male trauma patient**
- **unclear etiology of ALI**
- **intubated <48 hours**
- **NMB prior to ECMO**

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http://www.respscore.com/

KEY POINTS

- The failed organ needs to be able to get better, (or replaced or durably supported)
- The rest of the body needs to be in reasonably good shape
- Survival for VA ECMO is less than 50%; Survival for VV ECMO is greater than 50%
- Patients who need ECMO likely benefit more from the therapy the earlier it can be provided
- The heart and lungs are linked - in cases of severe cardio/pulmonary failure, both organs are typically affected, and the rest of the body ultimately suffers
- The depth of shock and gravity of pre-ECMO injury may be the most important variables

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SOME TRAUMA SPECIFIC KEY POINTS

- Alternative approach to cannulation may be necessary secondary to injury or condition
- Risk of bleeding may provoke discussion of altered anticoagulation strategy
- Trauma patients may require more interventions/imaging/OR trips/etc. The complexity of these activities while on ECMO should be planned for
- Other injuries may limit benefit of ECMO (maybe analogous to comorbidity?)
- Neurologic injury is not an absolute contraindication to ECMO, but common sense applies (unrecoverable/catastrophic injury, pre-ECMO ICH, etc. are not likely to benefit)
- It may be appropriate to continue support in patient with ICH while on ECMO. Should mandate discussion of altered anticoagulation strategy.

ECMO IN GENERAL

- ECMO is a viable treatment option for severe cardiac/pulmonary failure

- Challenges include:
  - Patient selection
  - Program size
  - Technical hurdles
  - Institutional support/cost

- ECMO services are a functional necessity for large transplant centers, whereas those without such programs may find difficulty

- Larger/regional ECMO centers are a wealth of information and opportunity

OUR EXPERIENCE

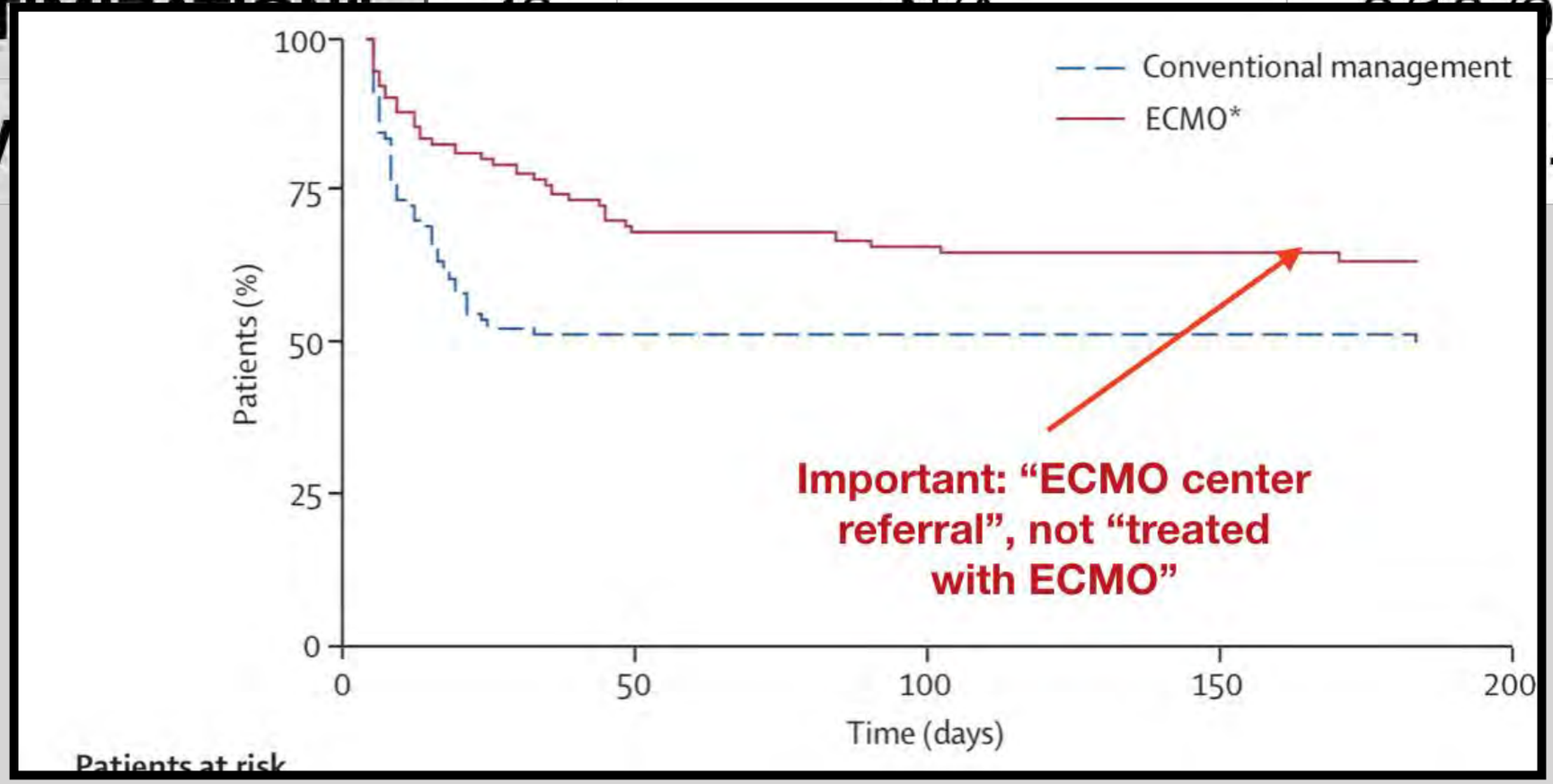
- From February 2017 through May 2018, the adult ECMO service at VUMC was **consulted 24 times for ECMO**
- All patients were evaluated at bedside by a physician member of the ECMO team within 30 minutes, and rapid assessment and initiation of ECMO, if indicated, was carried out at bedside
- **9/24 patients were placed on VV ECMO, with 89% survival and a mean run time of 171 hours**
- Three configurations have been employed: right IJ dual-lumen, femoral-IJ bicaval, and bifemoral
- Anticoagulation was held for long periods in 5/9 cases, there were no significant incidents of circuit clotting, and no unanticipated exchange of circuit components
- Multiple imaging studies and surgical procedures were performed, both in the operating room and at bedside, with no suggested increase in complications
- Providing a consultancy service allowed for additional eyes on the patient, and optimization plans led to recovery in several situations deemed “not optimized”

OUR EXPERIENCE

	AGE	RUN TIME	SURVIVAL
ALL CONSULTS	41	N/A	17/24 (70.8%)
“OPTIMIZATION”	49	N/A	9/10 (90%)
VV ECMO	35	171 HOURS (45-417)	8/9 (88.9%)

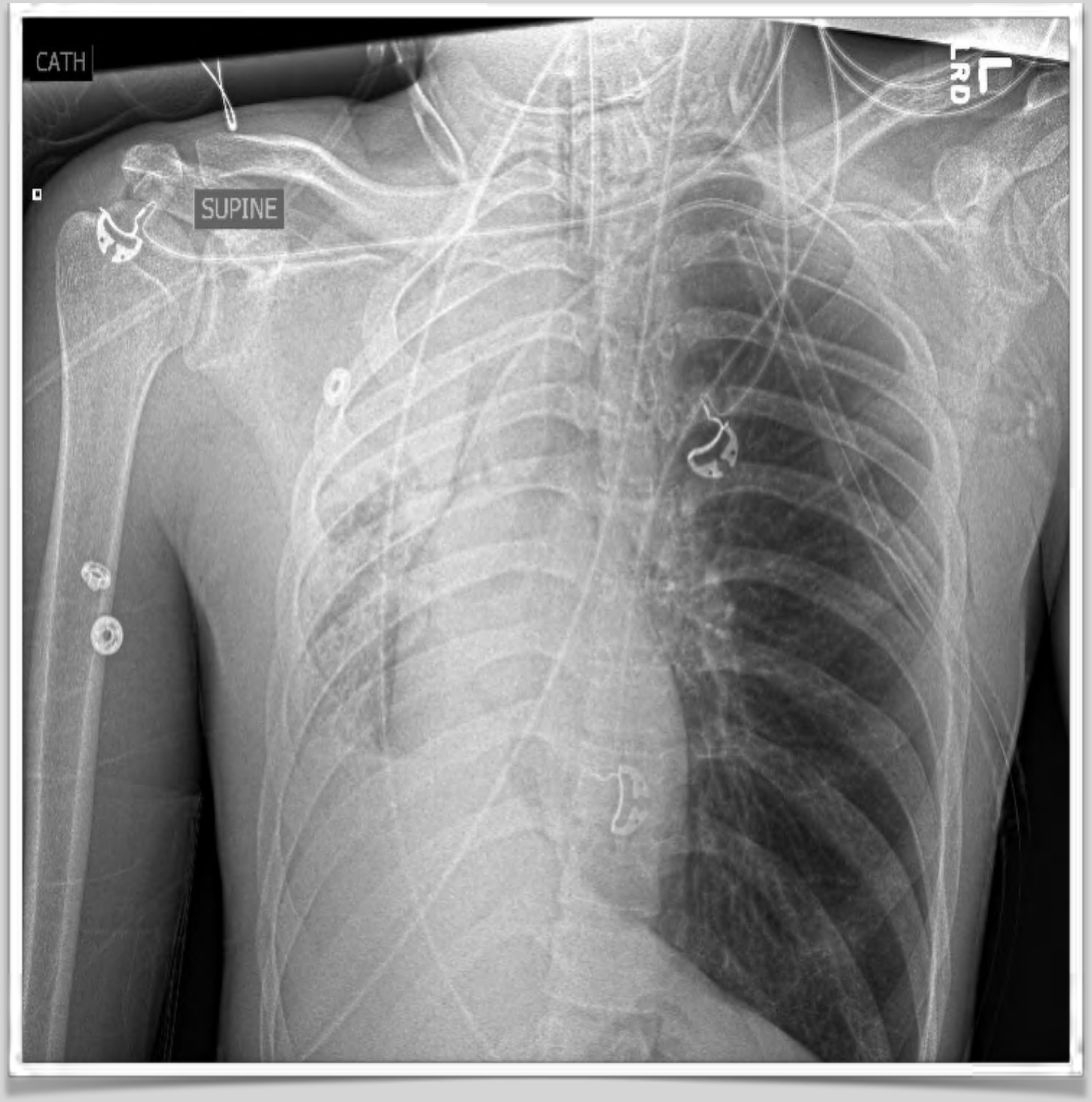
OUR EXPERIENCE

	AGE	RUN TIME	SURVIVAL
ALL CONSULTS	41	N/A	17/24 (70.8%)
"OPT		N/A	0%)
V			.9%)



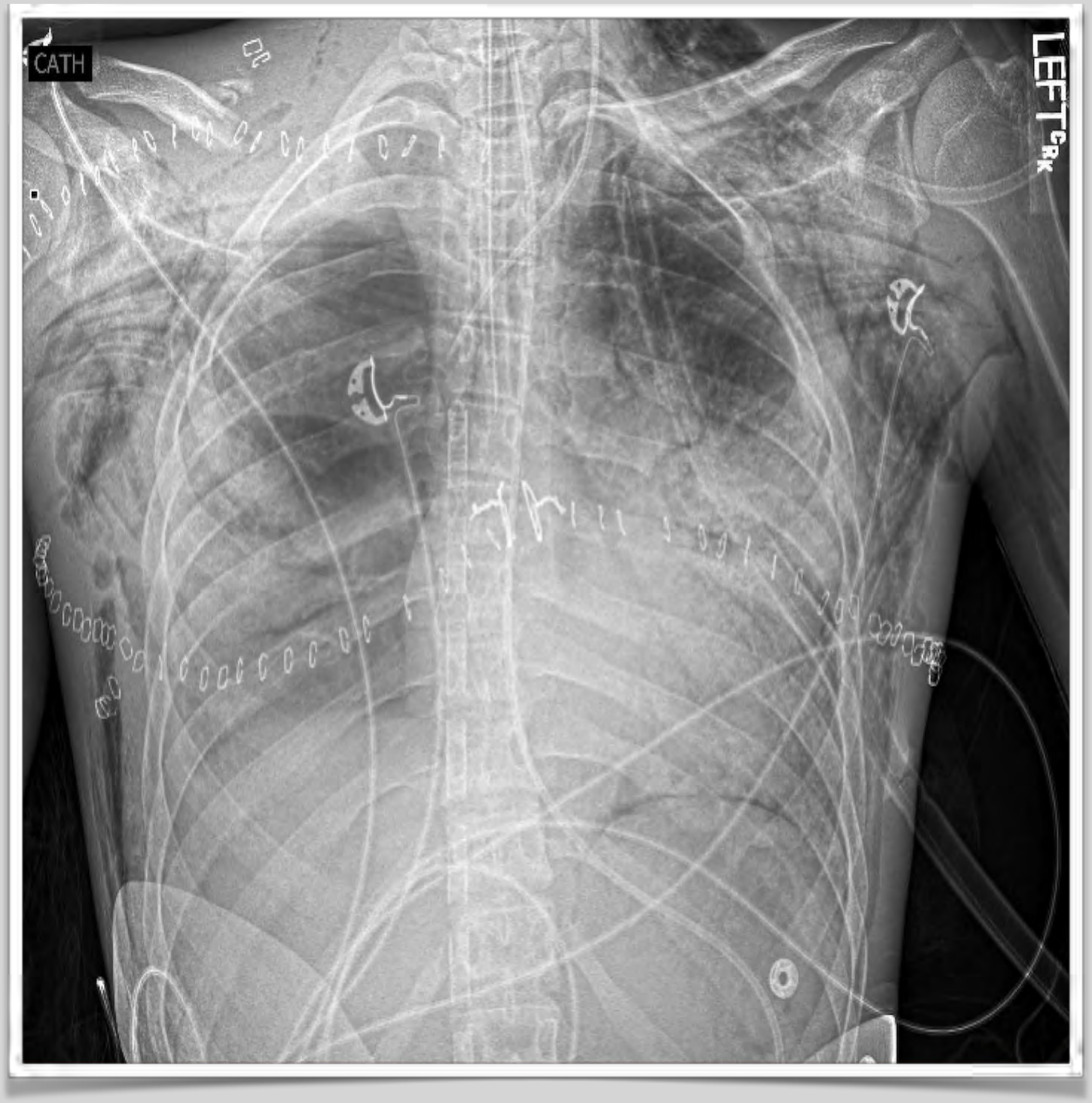
Flashback to CESAR

CASE 1



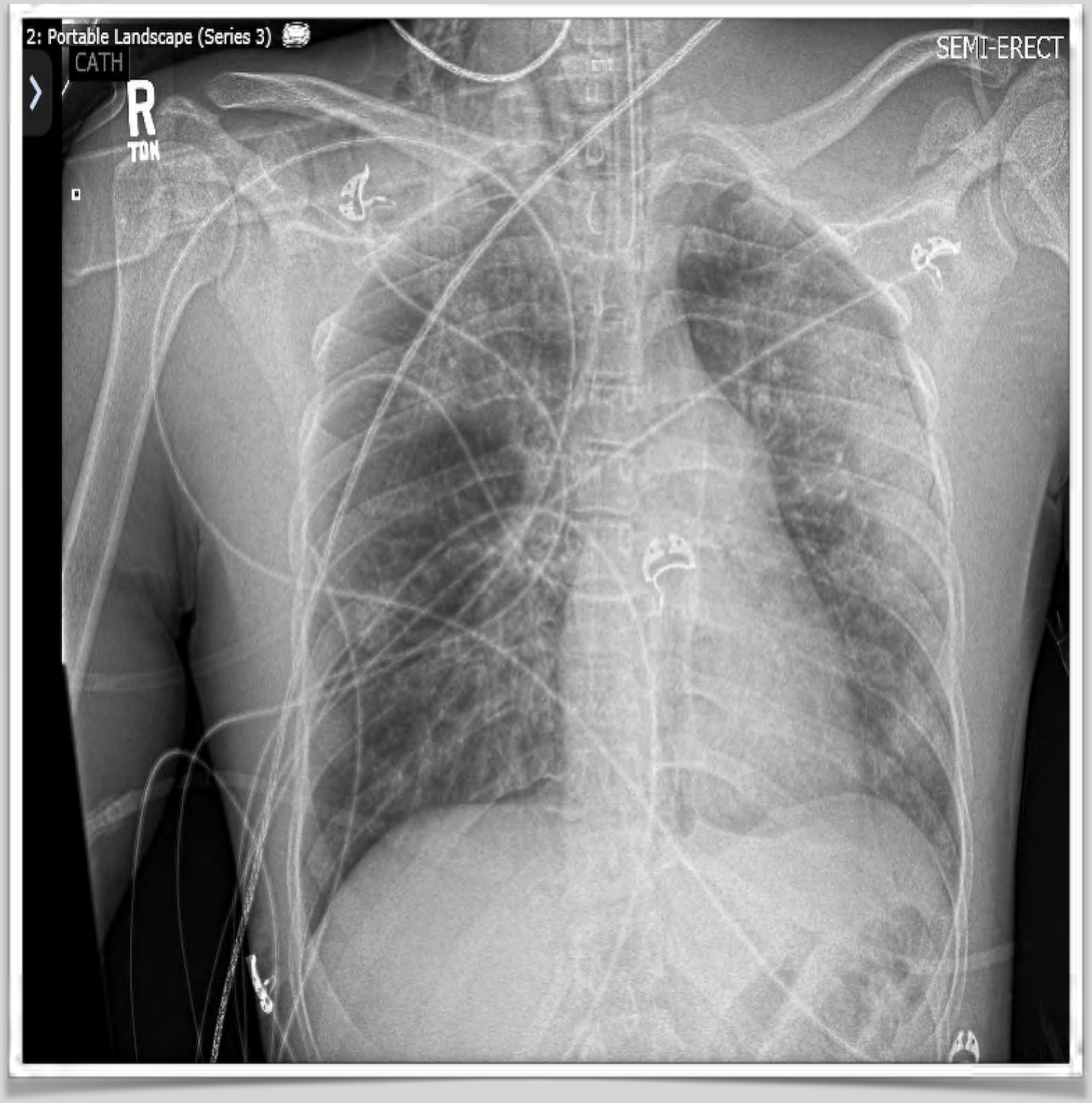
- Facial trauma with aspiration
- Complete collapse of right lung with mediastinal shift
- Severe hypoxemia, unable to tolerate bronchoscopy and therapy
- **4 days on VV ECMO - complete pulmonary recovery**

CASE 2



- Traumatic pneumonectomy R lung
- Extubated POD 1, but reintubated the next day, possible aspiration
- ARDS in remaining lung -> high ventilatory pressures -> bronchial stump breakdown
- **16 days on VV ECMO - complete pulmonary recovery**

CASE 3



- Blunt trauma with TBI
- Delayed ARDS secondary to pulmonary contusion and aggressive resuscitation, possible fat emboli
- Increased ICP worsened by need for high ventilator settings, hypoxia
- **11 days on VV ECMO - complete pulmonary recovery, neuro intact**

QUESTIONS?