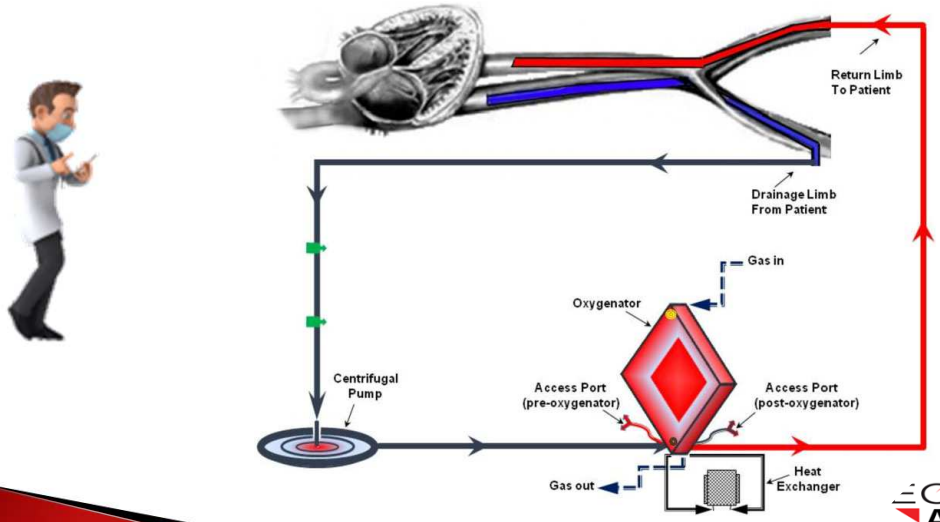
ECMO: Physiology and Patient Interactions

1

Disclosure

2

Let's Walk…



ECMO Advantage

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Venous (Drainage) Cannula

- Flow is dependent on cannula characteristics
  - Inner diameter
  - Length
  - Drainage and return ports
  - Location

ECMO Advantage

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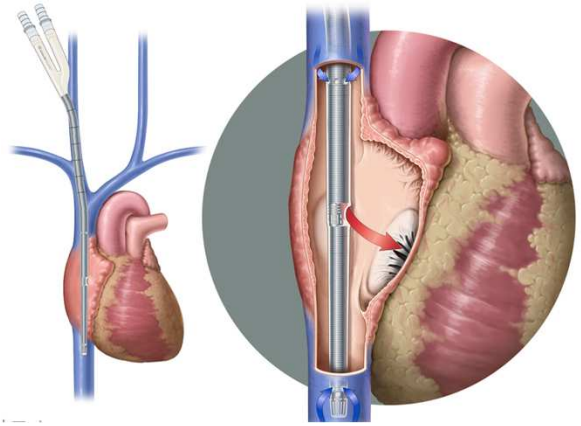
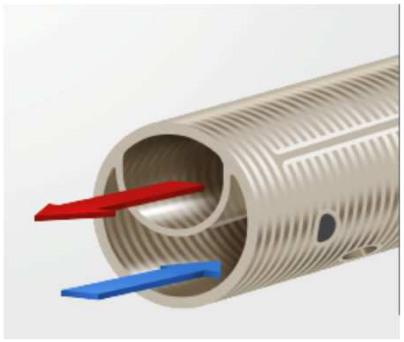
Dual Lumen Cannula (DLC)





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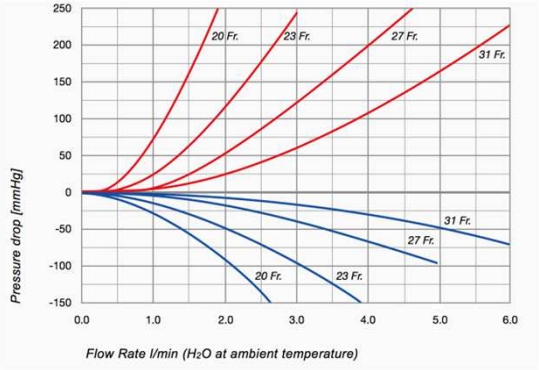
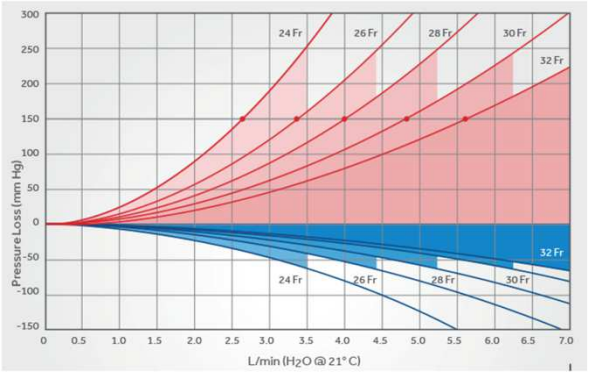
Dual Lumen Pressure Drop, Flow Chart





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Single Lumen Single Stage Venous Cannula

12-15 in (30.5 - 38.1 cm)

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Single Lumen Multi-Stage Venous Cannula

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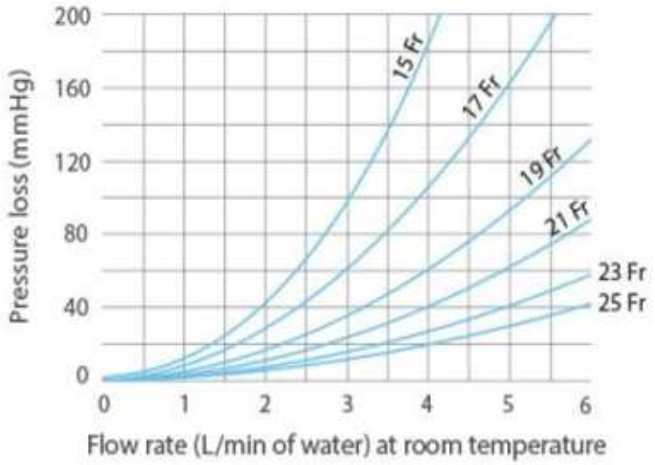
Single Lumen Pressure Drop, Flow Chart



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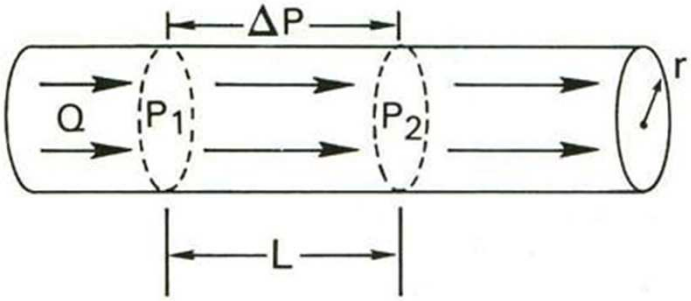
Poiseuille's Law



POISEUILLE'S LAW

$$Q = \frac{\Delta P \ r^4 \ \pi}{\eta L \ 8}$$

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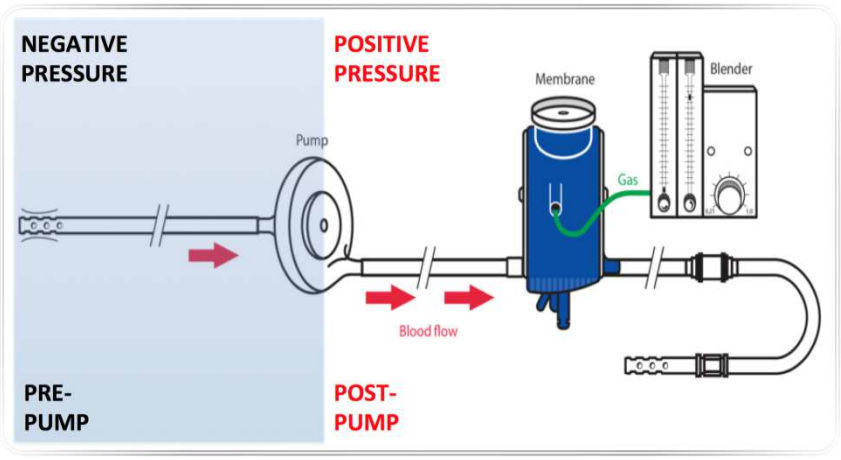
Pressures in the ECMO Circuit



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ECMO Physiology

- Preload
- Extracorporeal Output
- Afterload

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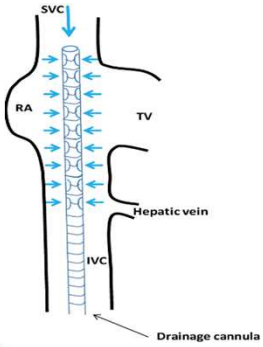
ECMO Preload

Limiting Factors…

Venous Cannula



Intravascular Volume

ECMO Advantage

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Extracorporeal Output

- **RPM's**

↓ Decreased rpm = ↓ Decreased Flow

↑ Increased rpm = ↑ Increased Flow

ECMO Advantage

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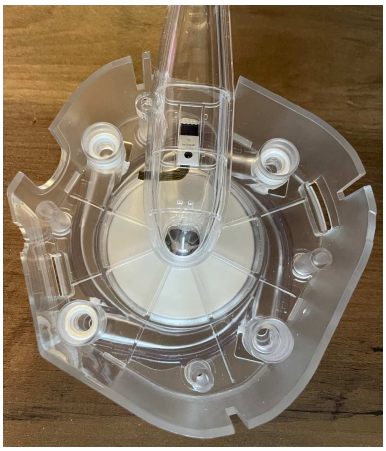
Centrifugal Pumps



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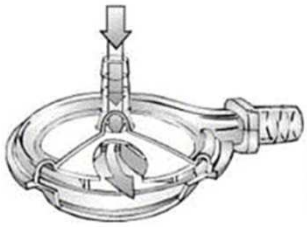
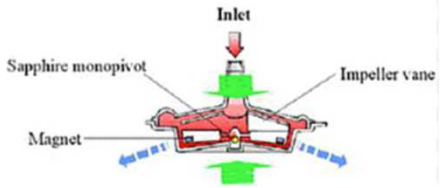
Centrifugal Pump Design





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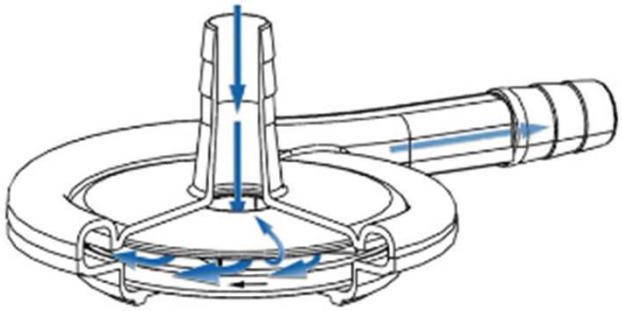
Centrifugal Pump Physics



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ECMO Membrane Lung

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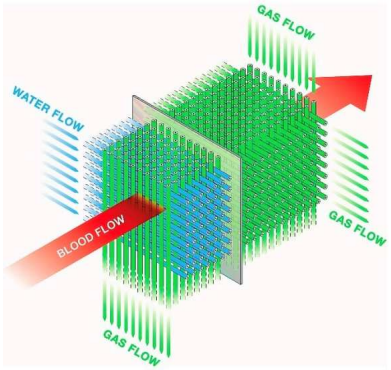
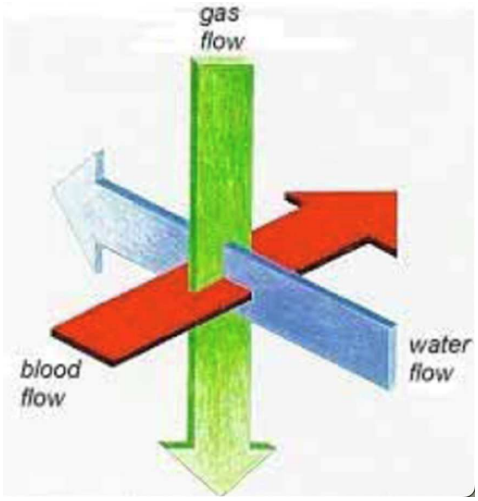
ECMO Membrane Lung





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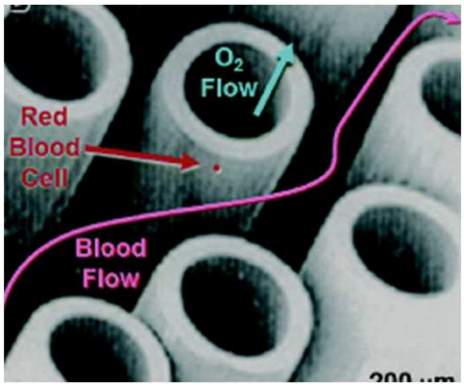
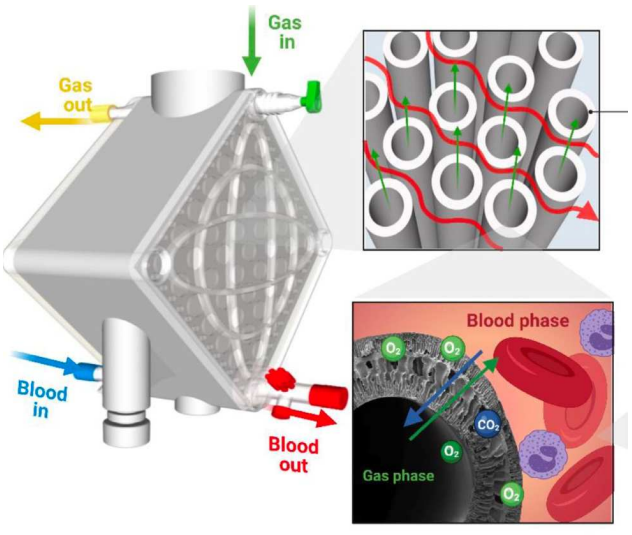
Closer Look…





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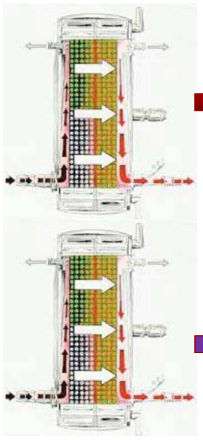
Rated Flow

"The MAXIMUM [ECMO] blood flow up to which the artificial lung can increase the inlet O2 saturation form 65± 5% to 95% with a hemoglobin of 12 g/dl."

SVO2 65%
Hgb 12
6 L/min



SaO2 95%

SVO2 50%
Hgb 12
6 L/min

SaO2 86%

ECMO Advantage

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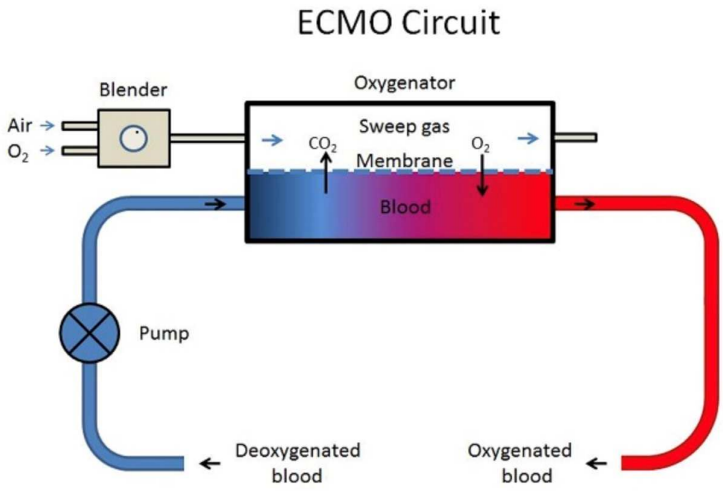
Gas Exchange in Membrane Lung



ECMO Advantage

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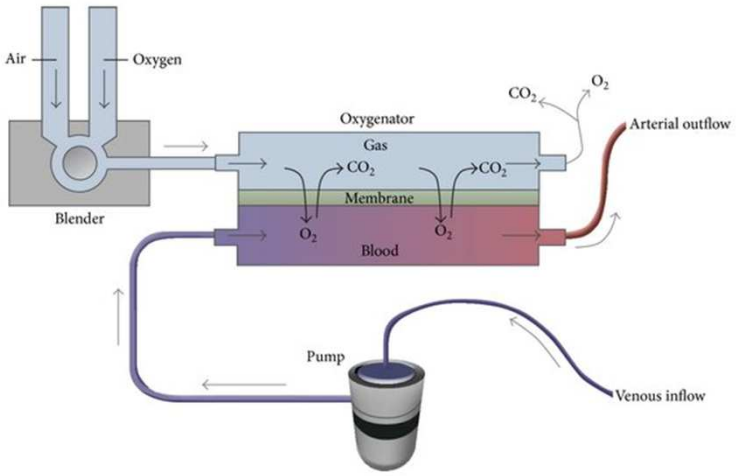
Gas Exchange in Membrane Lung



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V/Q Mismatch Membrane Lung

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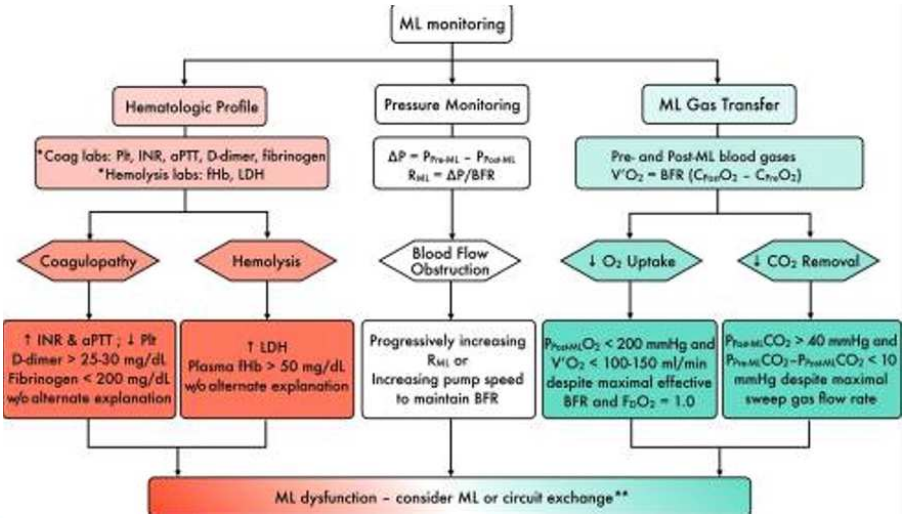
Is my Membrane Lung Failing?



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What about the ventilator?

Setting	ELSO Acceptable Range	ELSO Recommended Range	EOLIA Protocol	CESAR Trial
Inspiratory plateau pressure, cm H_2O	≤30	<25	≤24	20
Tidal volume	NR	NR	Adjusted to meet plateau pressure target	NR
PEEP, cm H_2O	≥10	10–24	≥10	10
F_{IO_2}	0.30-0.50	As low as possible to maintain saturations	0.30–0.50	0.30–0.50
Breathing frequency, breaths/min	4–30	4–15	4–30	10

ELSO = Extracorporeal Life Support Organization[19]
EOLIA = ECMO to Rescue Lung Injury in Severe ARDS[18]
CESAR = Conventional Ventilation or ECMO For Severe Adult Respiratory Failure[1]
NR = not reported

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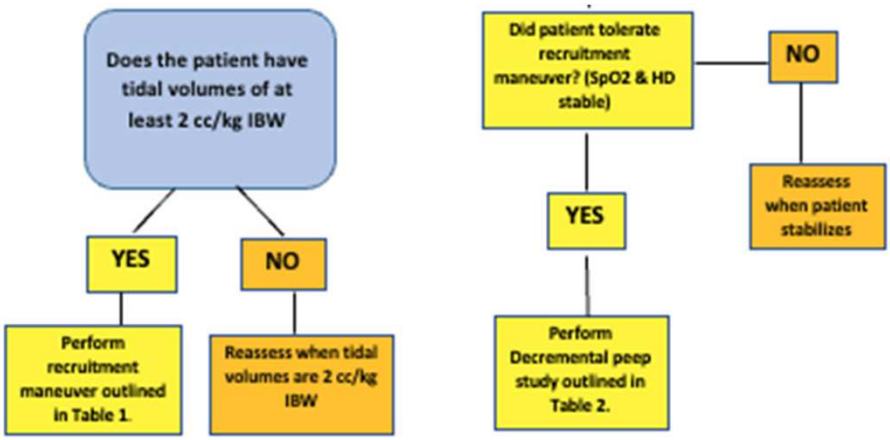
Recruitment Maneuvers?



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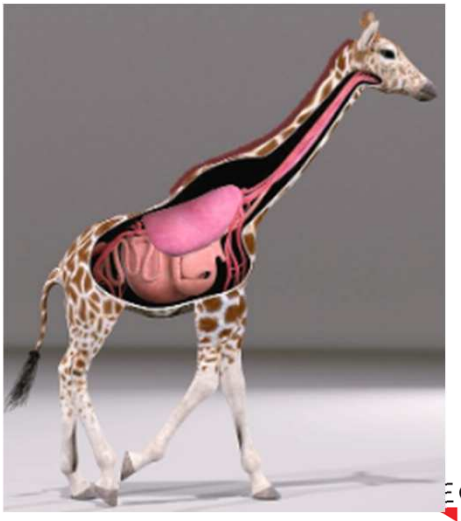
What about Aerosolized Medication?



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ECMO Afterload

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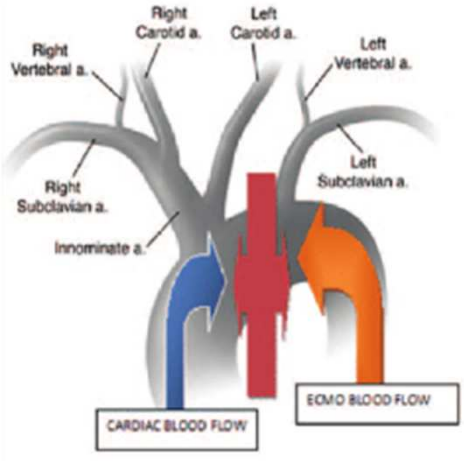
ECMO Afterload



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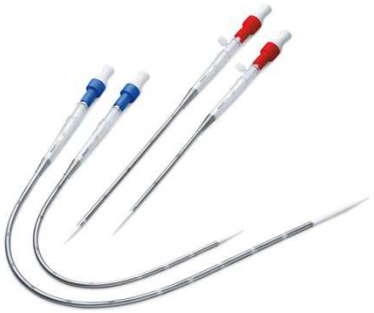
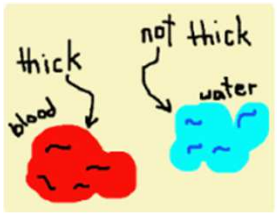
Afterload and Laminar Flow Factors

- Diameter
- Length
- Viscosity





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ECMO Preload and Afterload Key Concepts

Preload and flow are ***directly*** related, w/RPM constant
↑ preload = ↑ flow
↓ preload = ↓ flow

Afterload and flow are ***indirectly*** related, w/RPM constant
↑ afterload = ↓ flow
↓ afterload = ↑ flow

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Putting it all Together

1	5.2 Flow	3800 RPM	2
3	-80 PVen	150 Post	4
5	175 Pre	36.7 Temp	6
7	25 ▲	52 SVO_2	8

1. Flow
2. RPM's
3. Pre-pump pressure
4. Post membrane lung pressure
5. Pre-membrane lung pressure
6. Temp of blood
7. Delta P
8. SVO2

ECMO Advantage

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ECMO Detective

ECMO Advantage

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What do YOU think?

2100

5.2 Flow	3800 RPM
-80 PVen	150 Post
175 Pre	36.7 Temp
25 ▲	52 SVO_2

0100

3.9 Flow	3800 RPM
-115 PVen	143 Post
165 Pre	36.7 Temp
22 ▲	52 SVO_2

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Preload!

Potential Causes of Preload Issues:

- Decreased intravascular volume (patient)
- Venous limb circuit obstruction (mechanical)
- Venous cannula obstruction (mechanical)

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How do preload issues manifest?

5.2 Flow	3800 RPM
-80 PVen	150 Post
175 Pre	36.7 Temp
25 ▲	52 SVO_2

3.9 Flow	3800 RPM
-115 PVen	143 Post
165 Pre	36.7 Temp
22 ▲	52 SVO_2

At a set RPM, a PRELOAD issue will manifest as:

- ↓ Flow
- ↓ Pre/Post Membrane Pressures
- — Pre-pump pressure

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What do YOU think?

0800

5.2 Flow	3600 RPM
-80 PVen	150 Post
175 Pre	36.4 Temp
25 ▲	70 SVO_2

1000

4.1 Flow	3600 RPM
-66 PVen	210 Post
245 Pre	36.4 Temp
35 ▲	70 SVO_2

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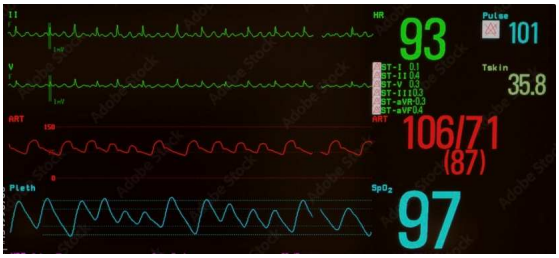
Afterload!

Potential Causes of Afterload Issues:

- Increased Mean Arterial Pressure (MAP) on VA ECMO (patient)
- Arterial limb circuit obstruction (mechanical)
- Arterial cannula obstruction (mechanical)



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How do afterload issues manifest?

5.2 Flow	3600 RPM
-80 PVen	150 Post
175 Pre	36.4 Temp
25 ▲	70 SVO_2

4.1 Flow	3600 RPM
-66 PVen	210 Post
245 Pre	36.4 Temp
35 ▲	70 SVO_2

At a set RPM, an AFTERLOAD issue will manifest as:

↓ Flow

↑ Pre/Post Membrane Pressures

✚ Pre-pump pressure

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What do YOU think?

0500	
4.4 Flow	3200 RPM
-80 PVen	127 Post
150 Pre	36.4 Temp
23 ▲	70 SVO_2

0600	
3.7 Flow	3700 RPM
-68 PVen	120 Post
142 Pre	36.4 Temp
22 ▲	67 SVO_2

ECMO Advantage

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ECMO Advantage

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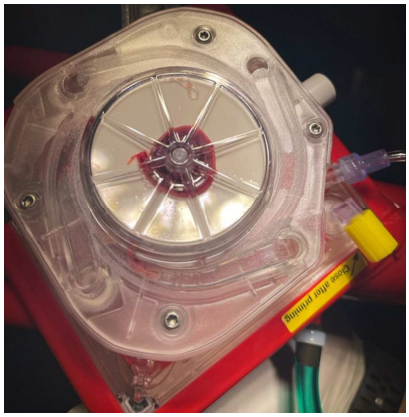
Extracorporeal Output! (aka Pump Flow)

Likely cause of Pump flow issues:



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How do output issues manifest?

4.4 Flow	3200 RPM
-80 PVen	127 Post
150 Pre	36.4 Temp
23 ▲	70 SVO_2

3.7 Flow	3700 RPM
-68 PVen	120 Post
142 Pre	36.4 Temp
22 ▲	67 SVO_2

Output issues will manifest as:

- ↓ Flow
- ↓ Pre/Post Membrane Pressures
- ✚ Pre-pump pressure

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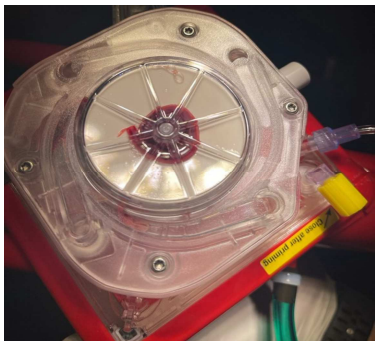
Clot in pump troubleshooting



ECMO Advantage

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All Things ECMO Newsletter

ECMO Advantage

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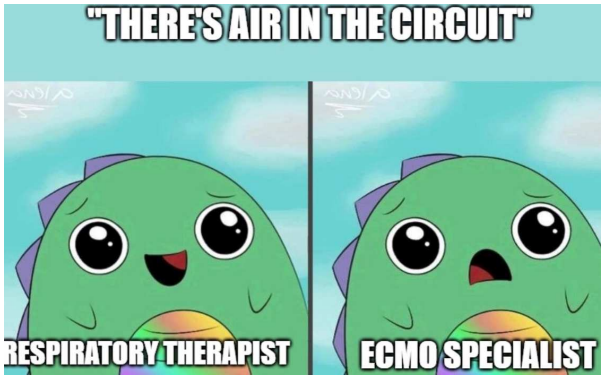
Thank you!



jeliene@ecmoadvantage.com

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