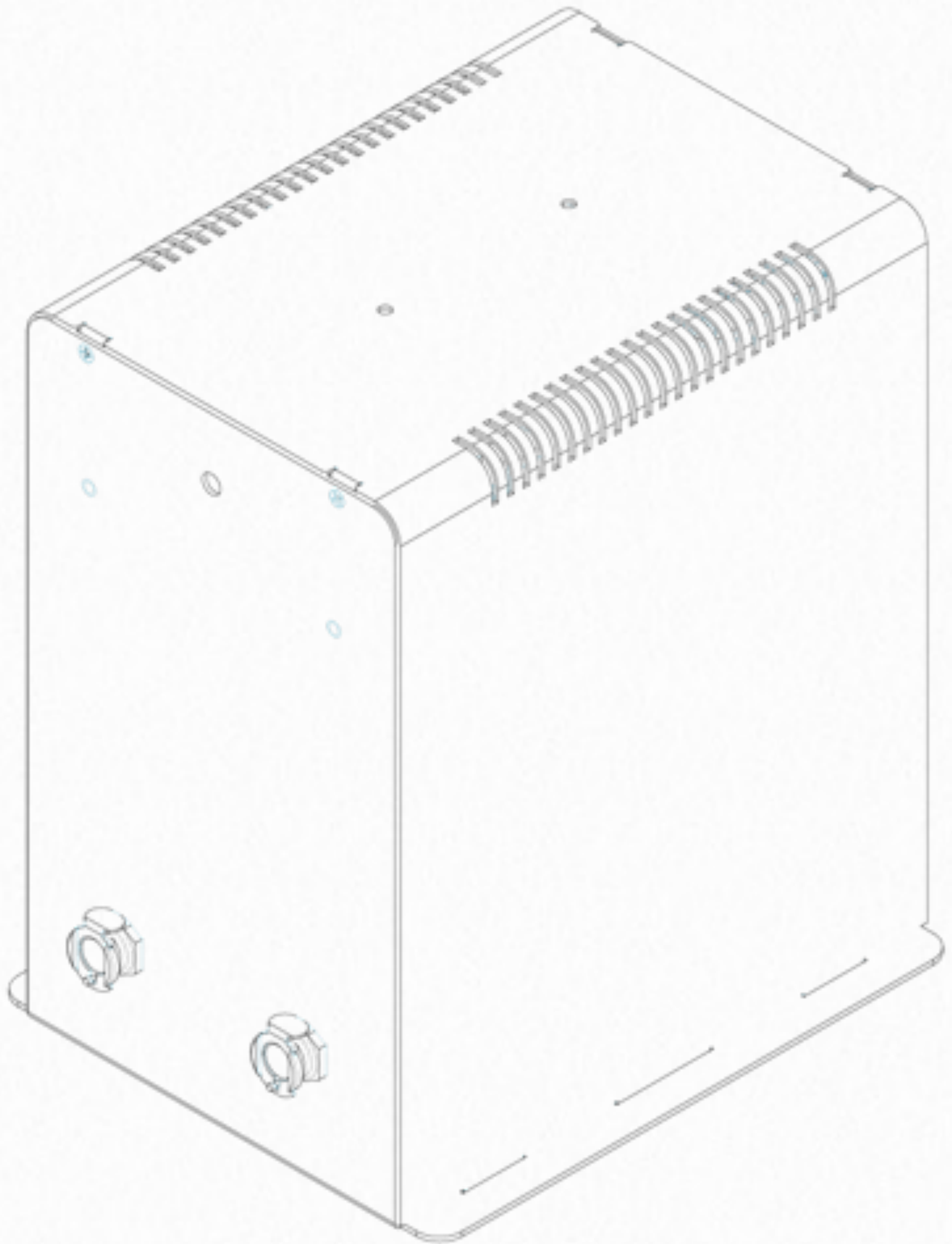
EigenFlow User Manual



Preface

In early 2011, I was asked to participate in the development of a simulation program for the pediatric ECMO group at Riley Children's Hospital. From this experience, I discovered the need for a high fidelity device which would allow an ECMO coordinator the ability to modify the ECMO process in a manner that was remote and unobtrusive. I developed EigenFlow as a solution to that need. This process has proceeded through four prototypes, countless discussions, simulations, site visits, international meetings of ECMO specialists and simulation educators. My desire is that EigenFlow will provide a realistic simulation experience for you and your team.

This manual is made up of 6 chapters with an entire chapter filled with scenarios for your team to incorporate into your simulations.

Paul Curtis
Paul Curtis
President
Curtis Life Research

Copyright © 2015 by Curtis Life Research LLC

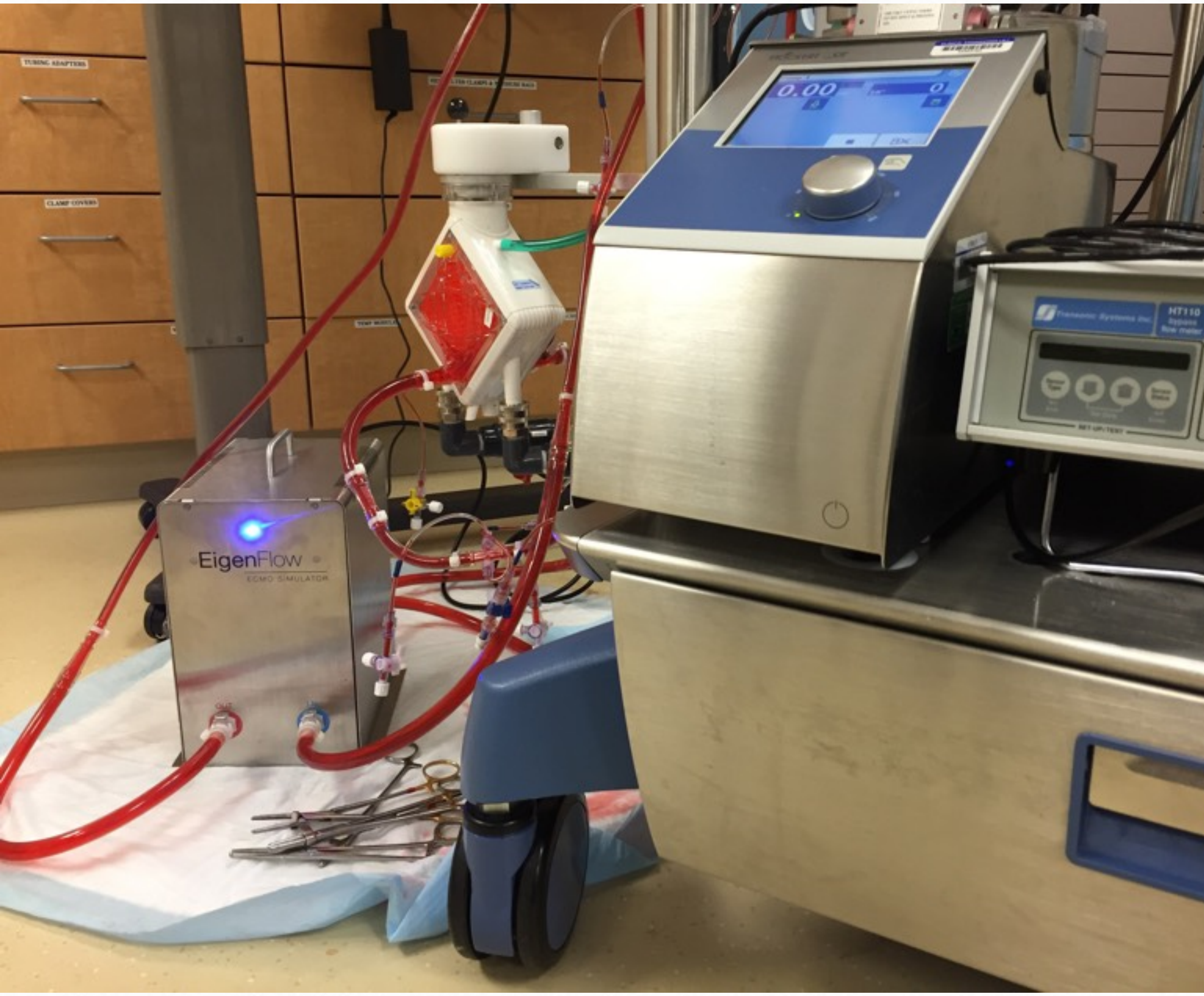
All rights reserved. No part of this work covered by the copyright hereon may be reproduced or used in any form or by any means - graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems - without permission of the publisher.

Table of Contents

1

Introduction

> **“Color my life with the chaos of trouble.”**
>
> *– Belle and Sebastian*



IMPORTANT SAFETY INSTRUCTIONS

Read these operating instructions carefully before using the unit. Follow the safety instructions on the unit and the applicable safety instructions listed below. Keep these operating instructions handy for future reference.

1. Read these instructions.

2. Keep these instructions.

3. Heed all warnings.

4. Follow all instructions.

5. Do not submerge or pour water on this apparatus.

6. Do not block any ventilation openings. Install in accordance with the manufacturer's instructions.

7. Do not install near any heat sources such as radiators, heat registers, stoves, or other apparatus (including amplifiers) that produce heat.

8. Do not defeat the safety purpose of the polarized or grounding-type plug. A polarized plug has two blades with one wider than the other. A grounding-type plug has two blades and a third grounding prong. The wide blade or the third prong are provided for your safety. If the provided plug does not fit into your outlet, consult an electrician for replacement of the obsolete outlet.

9. Protect the power cord from being walked on or pinched particularly at plugs, convenience receptacles, and the point where they exit from the apparatus.

10. Only use attachments/accessories specified by Curtis Life Research.

11. Use only with the cart, stand, tripod, bracket, or table specified by the Curtis Life Research, or sold with the apparatus. When a cart is used, use caution when moving the cart/apparatus combination to avoid injury from tip-over.

12. Unplug EigenFlow during lightning storms or when not in use.

13. Refer all servicing to qualified service personnel. Servicing is required when the apparatus has been damaged in any way, such as power-supply cord or plug is damaged, liquid has been spilled or objects have fallen into the apparatus, the apparatus has been exposed to rain or moisture, does not operate normally, or has been dropped.

CAUTION: TO REDUCE THE RISK OF ELECTRIC SHOCK, DO NOT OPEN OR MODIFY POWER SUPPLIES. **DO NOT USE EIGENFLOW ON HUMANS**

General Safety Instructions

- EigenFlow is used to perform and train ECMO Specialists to troubleshoot extracorporeal circulation during simulated cardiopulmonary perfusion. EigenFlow is not for human use or for use on human subjects. Any use beyond this specification is not in accordance with the regulations and CURTIS LIFE RESEARCH LLC will not assume any liability for damage in such a case. Usage in accordance with regulations also includes compliance with the user manual, as well as repair and maintenance according to the maintenance instructions.

- Relevant accident prevention measure according to existing local policy and employees' health and safety regulation must be complied with. CURTIS LIFE RESEARCH LLC will not accept any liability for damage due to non-compliance with these regulations

- CURTIS LIFE RESEARCH LLC will not assume any liability for injuries and/or damage caused by failure to observe the safety instructions or by the operator not taking due care. This also applies if the operator's duty to take due care has not been specifically expressed to the user.

- EigenFlow has been designed according to current state-of-the-art technology and accepted safety standards. Even so, danger may arise for the user or for other equipment during operation

- EigenFlow must be operated and maintained by trained and qualified personnel only.

- EigenFlow may only be used when the equipment is in good technical running order and, when used, in accordance with the applicable regulations and the operating instructions. Be sure to take note of cautions and warnings.

- Personnel operating the machine must have acquainted themselves thoroughly with the user manual prior to working on the machine.

- Do not execute any modifications or extensions to EigenFlow unless they have been tested and approved by CURTIS LIFE RESEARCH LLC. CURTIS LIFE RESEARCH LLC cannot assume any liability or responsibility for misuse.

Accessory

Check the supplied accessories before using this unit

1 EigenFlow 12V Power Adapter

1 iPod Touch preloaded with EigenFlow

1 10” Lilliput LCD monitor

1 Lilliput LCD monitor power adapter

1 6’ HDMI Cable

1 1610 Pelican® Case

1 3-Dmed® ECMO Cannulation Kit (optional)

1 Air Tubing with Luer Lock

3 3-Dmed® Pediatric Neck Pads (optional)

10 Pediatric/Adult Acetal Connectors

10 Zip Ties

- Product numbers correct as of June 2015. These may be subject to change.
- Do not use AC power supply cord and Wireless LAN Adaptor with other equipment.

2

Getting Started

Setting Up Your EigenFlow

Your EigenFlow is designed so that you can set it up quickly and start using it right away. The following pages take you through the setup process, including these tasks:

- Plugging in the power adapters
- Connecting the cables
- Connecting EigenFlow to an ECMO Machine
- Turning on your EigenFlow
- Connecting your iOS device
- Priming Valves
- Running a scenario

Step 1: Connecting EigenFlow To Your ECMO Machine

Connecting EigenFlow to your ECMO Machine requires you to modify an ECMO Circuit that will be interposed into your EigenFlow through acetal connectors. This modification requires the user to splice an ECMO Circuit at a location of the user's choosing. Recommended locations can be found on page 10, in the Chapter: "Selecting Locations For EigenFlow Placement."

After selecting two locations to splice into, cut the tubing and add couplers to extend the circuit or add acetal connectors to connect it to your EigenFlow. Secure your connections with zip ties. Next, place EigenFlow on the floor adjacent to your ECMO cart, it is recommended to have EigenFlow as close to the ECMO circuit as possible.
Note: Long extensions to the ECMO circuit will create an unnecessary resistance to the ECMO pump, generating low flow rates at high pump RPMs.

Connect the acetal connectors from your splice to your EigenFlow by pushing in the acetal connector into the corresponding ECMO socket until it clicks. Follow the direction of blood flow at your splice point, this will be the direction you will need to connect to your EigenFlow.

Finally, connect the green air tubing with a luer lock along the ECMO circuit to a place where you would like to inject an air embolus.

Step 2: **Plug In the Power Adapter**

Plug in the Power Adapter labeled "EigenFlow" from a wall outlet to the barrel adapter post on the top left side on the back of your EigenFlow.

Next, plug in the power adapter labeled "Lilliput LCD" from a wall out to the barrel adapter post on the backside of your Lilliput LCD Display.

Step 3: **Connect Your Cables**

Using the HDMI Cable, connect the Lilliput LCD to the EigenFlow. The HDMI ports are located on the back side of the EigenFlow and the Lilliput LCD.

Step 4: **Turning On Your EigenFlow**

To turn on EigenFlow, toggle the power switch on the back of EigenFlow from "0" to "I". When you turn on EigenFlow, you should see the red status indicator light (it should stay on). It takes EigenFlow a few moments to execute its initialization process. After it starts up, the EigenFlow Blood Monitor screen will be white and ready for you to use.

Problems Turning On EigenFlow?

Nothing happens when you press the power switch

- If the EigenFlow doesn't startup, check your power connections including the onboard fuse located inside EigenFlow.
- If EigenFlow still fails to startup, please call or text our technical support line at: (317) 942-0727

EigenFlow freezes upon startup or blood monitor isn't displayed

This may indicate the memory inside EigenFlow has become corrupted. Please restart EigenFlow and call our technical support line at: +1 (317) 942-0727

Step 5: Connecting Your iOS Device

EigenFlow App

Turn on your iPod Touch *(your passcode is the 4-digit serial number on the back of your iPod Touch)* or iOS device and open the EigenFlow App. Once open, touch the "Connect" button inside the Thrombosis tab to see a list of EigenFlow connections. Select your device and watch the EigenFlow LED status indicator turn from Red to Blue. Blue indicates you are connected. Red indicates you are powered on but not connected.

RSSI values will fluctuate between different negative numbers. These numbers represent the signal strength of your Bluetooth connection. The more negative the number, the weaker your connection.

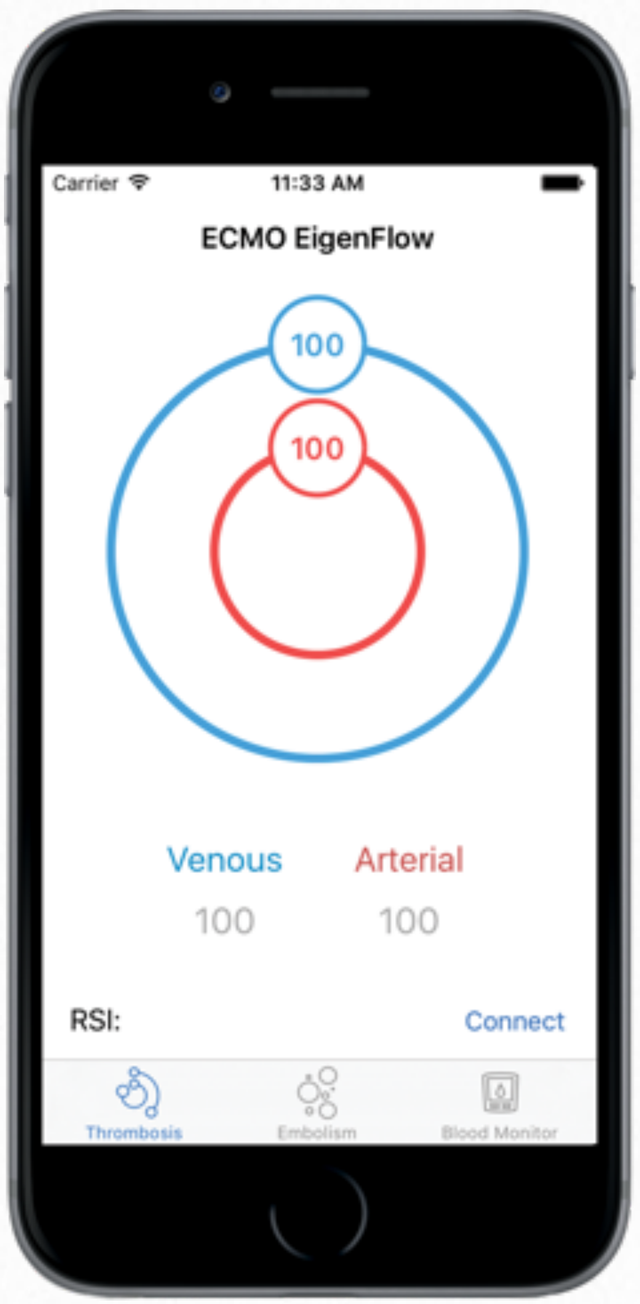


Figure 1: OPEN Valves

Step 6: Priming Valves

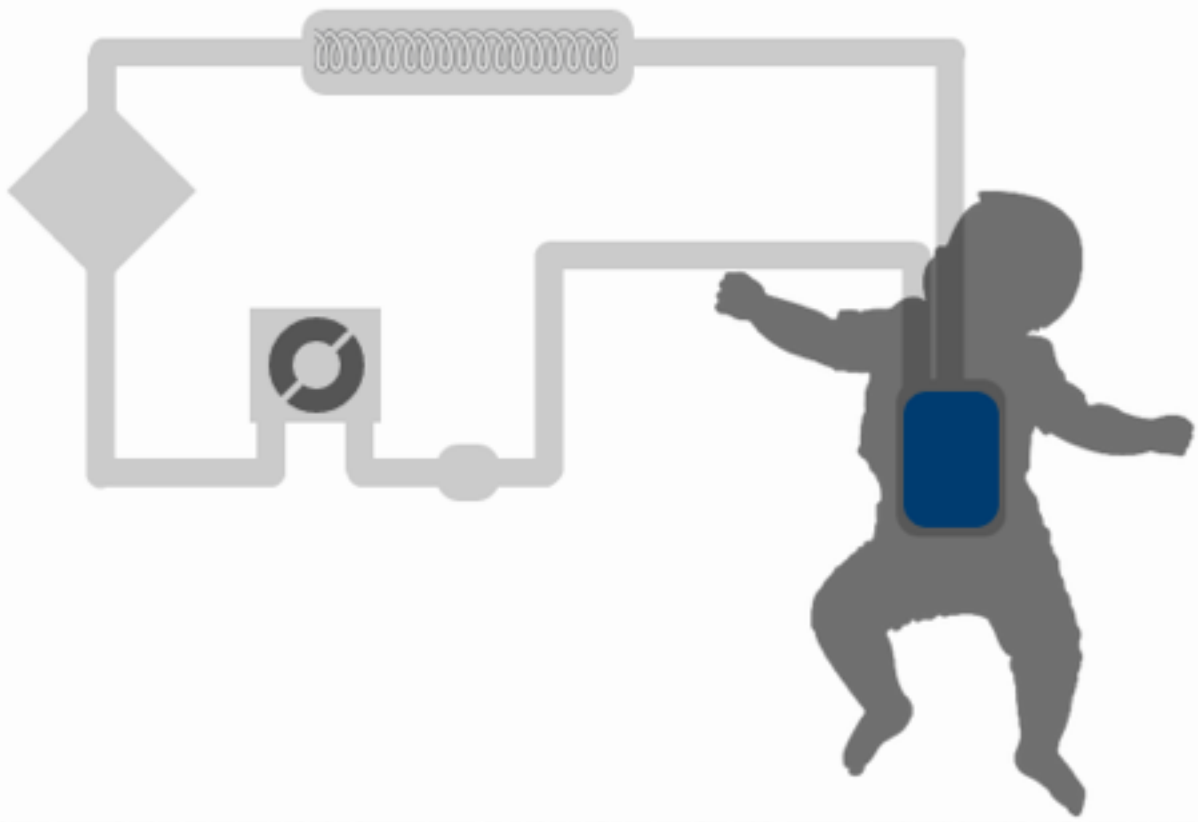
To prime the valves, select the Thrombosis tab and move the arterial and venous controls both to '100' (OPEN) as seen in Figure 1. Setting the arterial and venous controls to 100 will completely open your valves. After opening your valves, air will be introduced into the ECMO circuit. To remove the air, transport the air bubbles to the oxygenator and remove air with a syringe. Next, tilt EigenFlow back and forth to move any air that is trapped inside of your EigenFlow into the ECMO circuit.

Step 7: Running A Scenario

You are now ready to run an ECMO scenario. EigenFlow combined with a simulated patient monitor will complete the ECMO Simulation experience. To learn more see "Clinical Scenarios" on page 25.

3

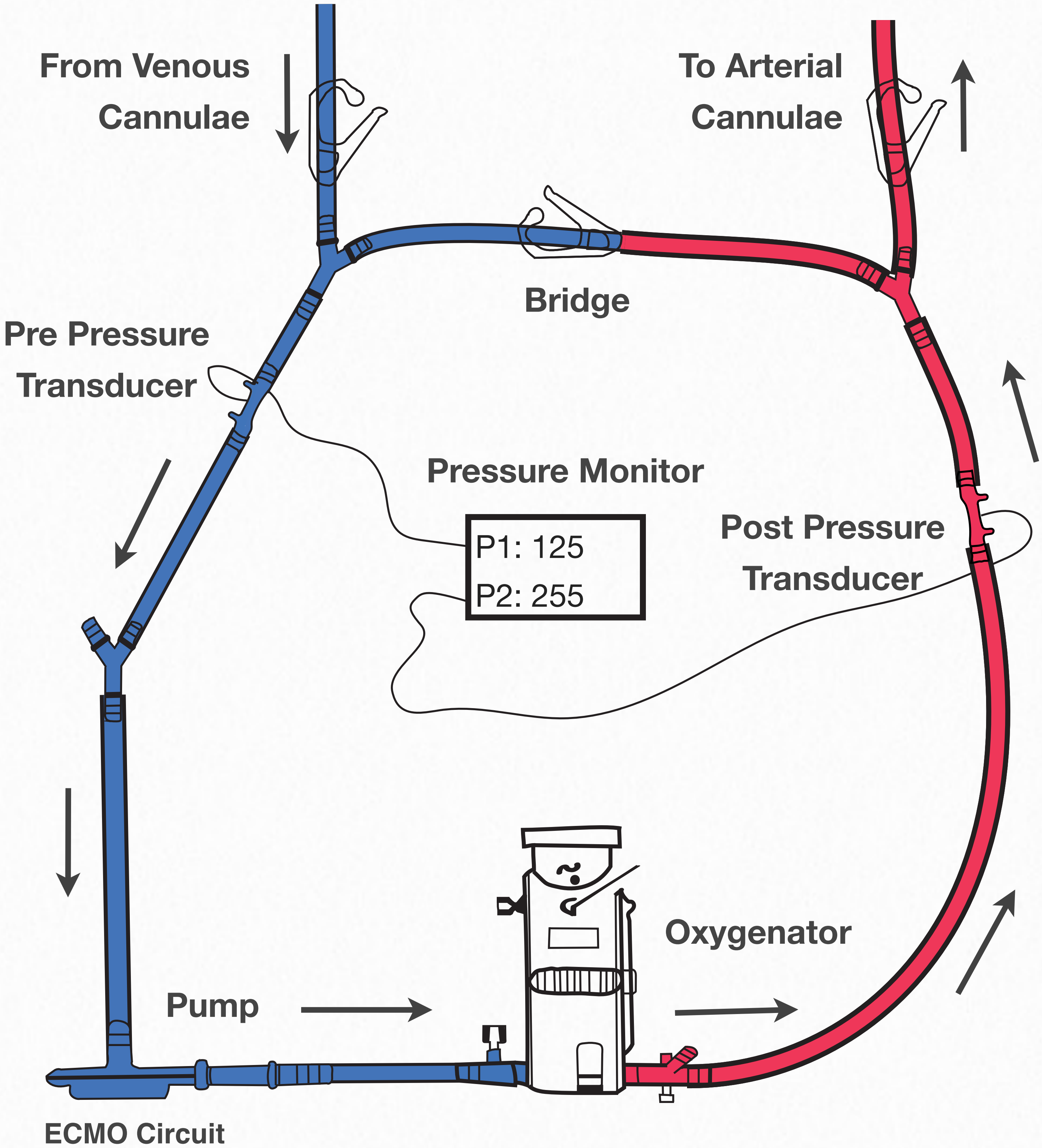
Selecting Locations For EigenFlow Placement



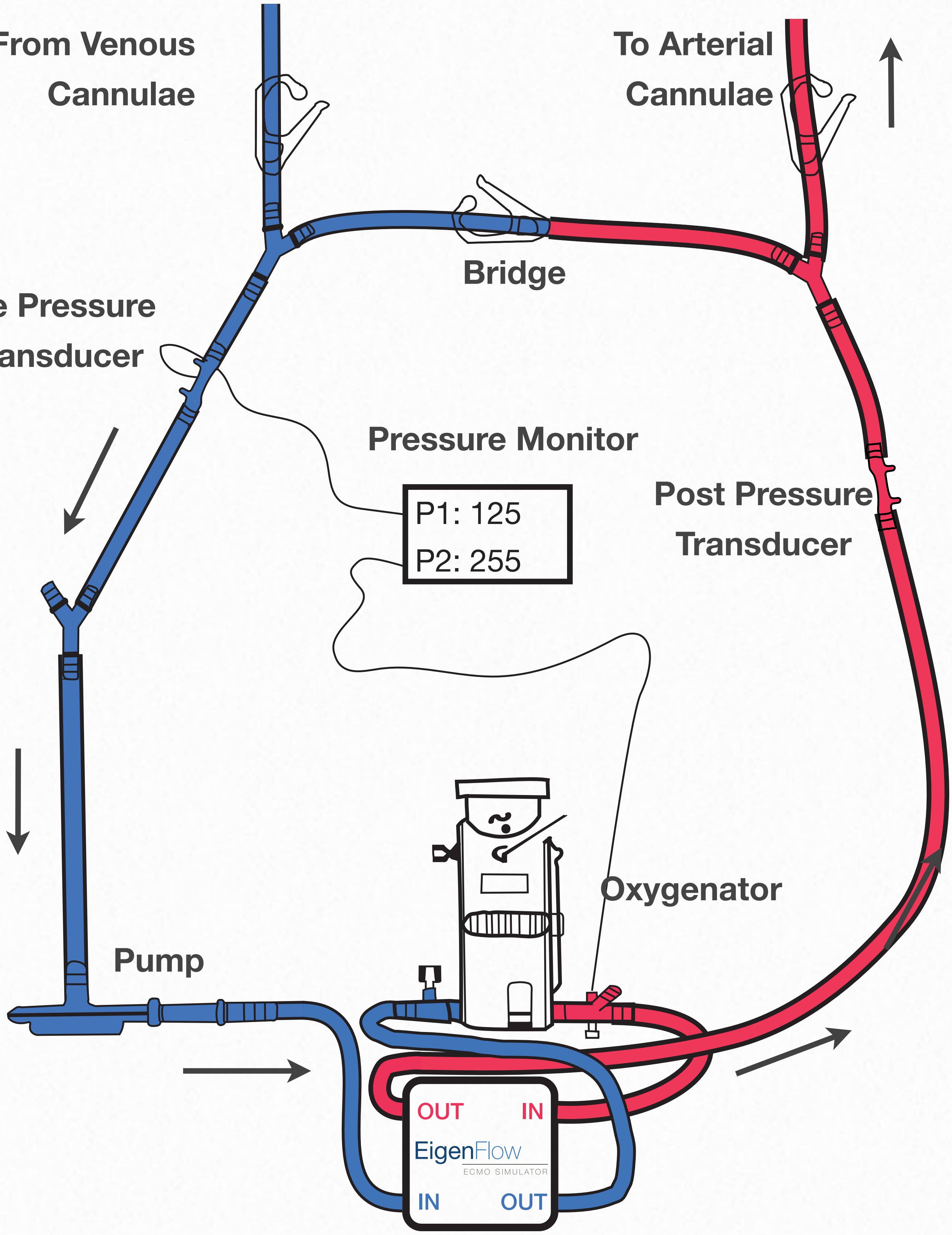
Selecting a location to interpose EigenFlow requires an ECMO tubing circuit that can be dedicated to training. ECMO tubing will need to be modified to be able to connect to your EigenFlow.

As interposition points are selected, the instructor must note the direction of flow through the circuit. EigenFlow interposition can create a wide variety of scenarios. Let's examine a few of these in detail.

Pre & Post Pressures



Pre and post pressure connections are the most common interposition points made with an EigenFlow. Choosing points before and after the pressure transducers will allow you to change the pressure and flow characteristics of your ECMO Circuit. This configuration will allow you to simulate an oxygenator failure, outlet obstruction, and inlet obstruction.



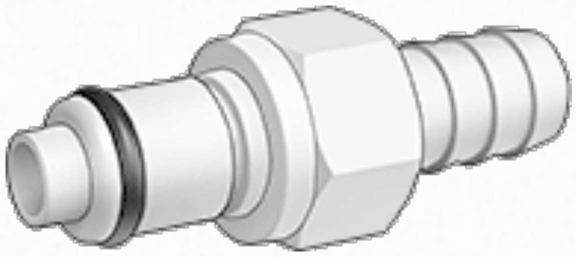
Step 1: Cutting your ECMO circuit

Cut your ECMO circuit before and after the oxygenator..

Note: If your circuit is primed with fluid, clamp before and after your splice point.

Step 2: Insert Acetal Connectors

If you are connecting to a pediatric ECMO circuit, place the 1/4” acetal connectors to the ends of the spliced ECMO circuit tubing. If you are connecting to an adult ECMO circuit, place the 3/8” acetal connectors to the ends of the spliced ECMO circuit (Figure 2).



Acetal Insert Connector

Figure 2: Acetal connector placed on spliced Adult ECMO tubing, secured with zip tie.

Step 3: Connect To Your EigenFlow

Connecting ECMO circuit tubing to your EigenFlow requires you to note the direction of flow through your ECMO circuit. Valves located inside EigenFlow works best when the flow is in the correct direction. Let’s take a look at a few examples.

Figure 3 demonstrates the direction of flow before cutting the ECMO circuit on the venous side. Figure 4 shows the flow through the circuit after cutting and inserting acetal connections. Flow direction is still noted after tube separation. The tail of the arrow after the separation will become the IN connection on your EigenFlow and the arrowhead end will become the OUT connection on your EigenFlow. Figure 5 and Figure 6 show how the flow direction determines how you connect to your EigenFlow. Repeat for arterial side.

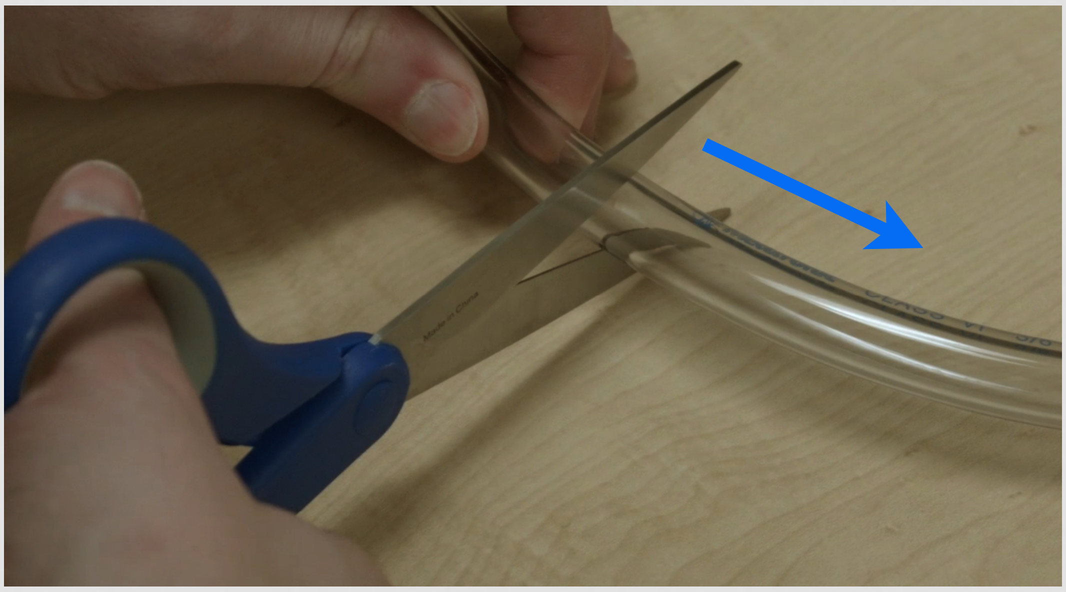


Figure 3: Note direction of flow before cutting ECMO tubing

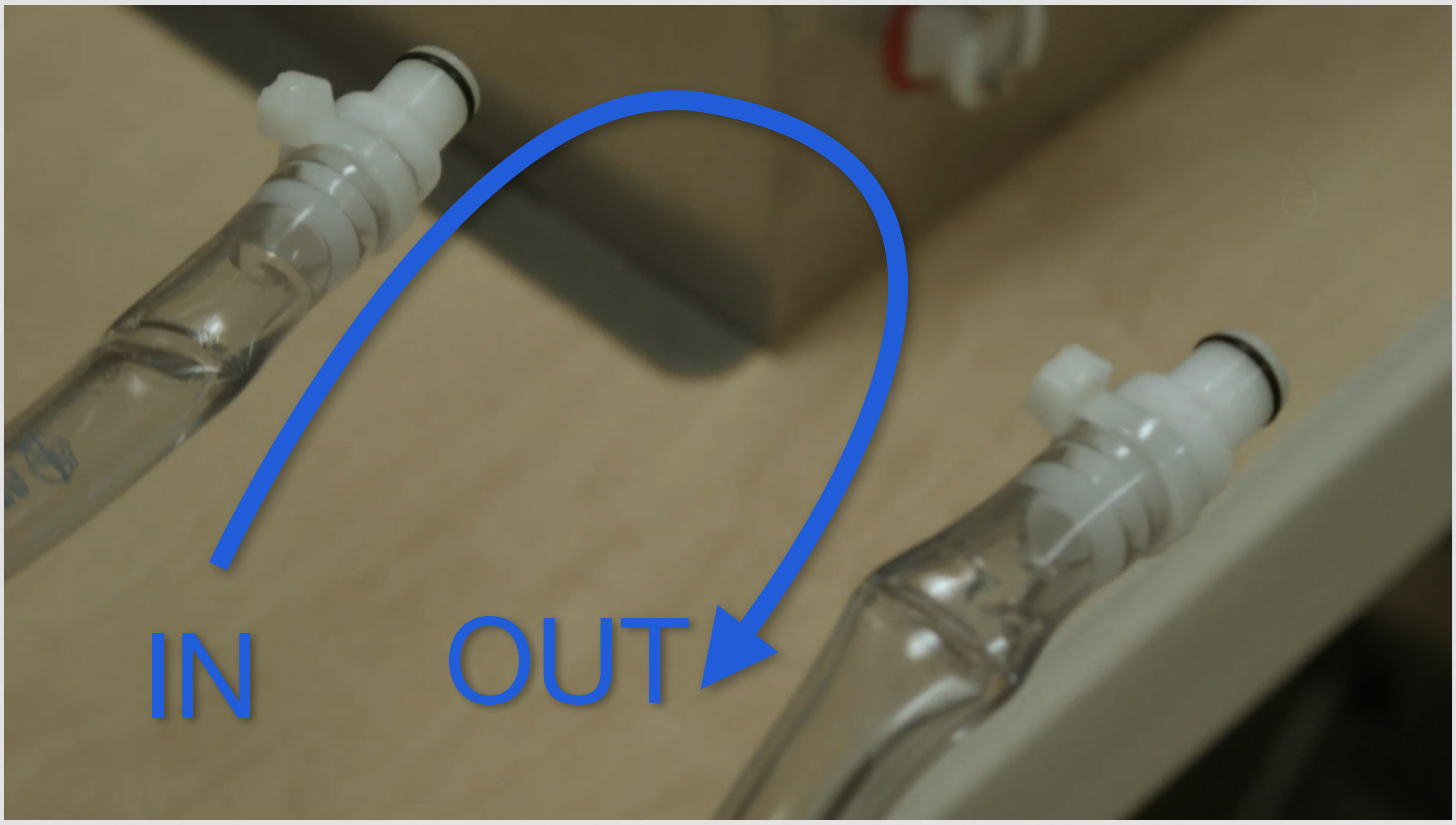


Figure 4: Direction of flow after cutting and inserting acetal connector

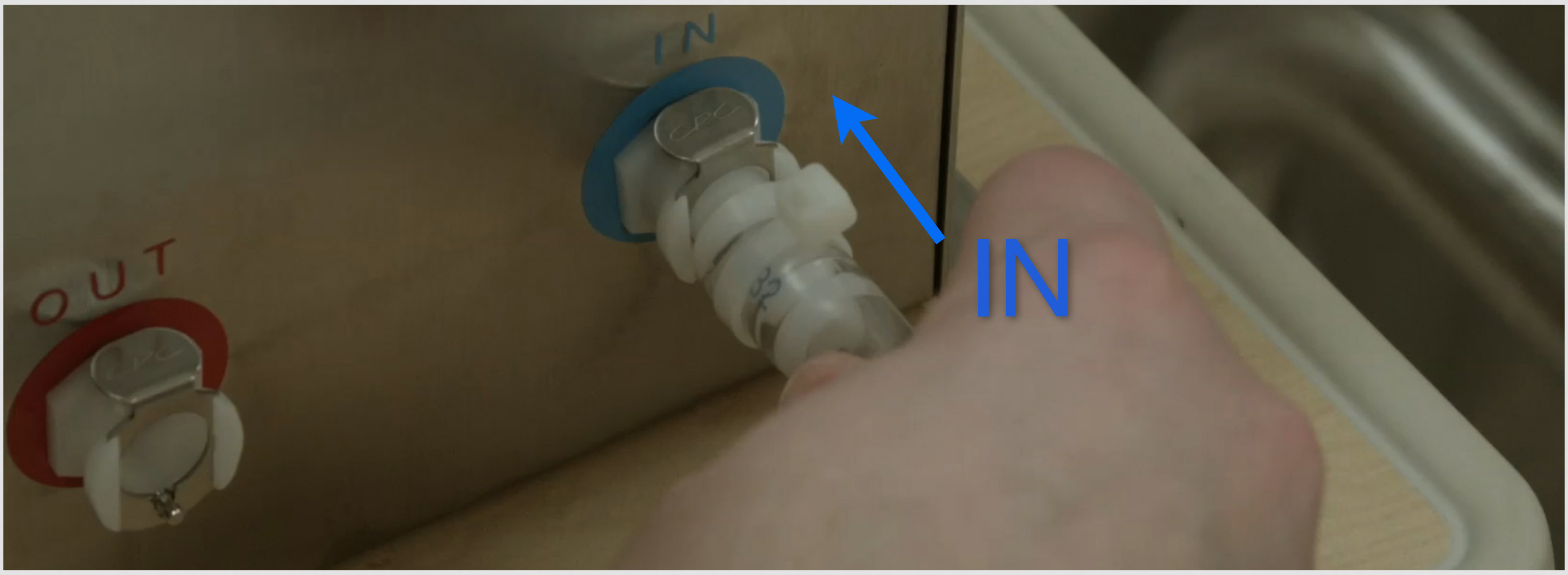


Figure 5: Connecting the venous IN acetal connector to the IN on your EigenFlow

Step 4: Priming Valves

To learn how to prime your ECMO Circuit see Step 6 in “Getting Started” on page 8.

Step 5: Running A Scenario

To learn more see “Clinical Scenarios” on page 25.

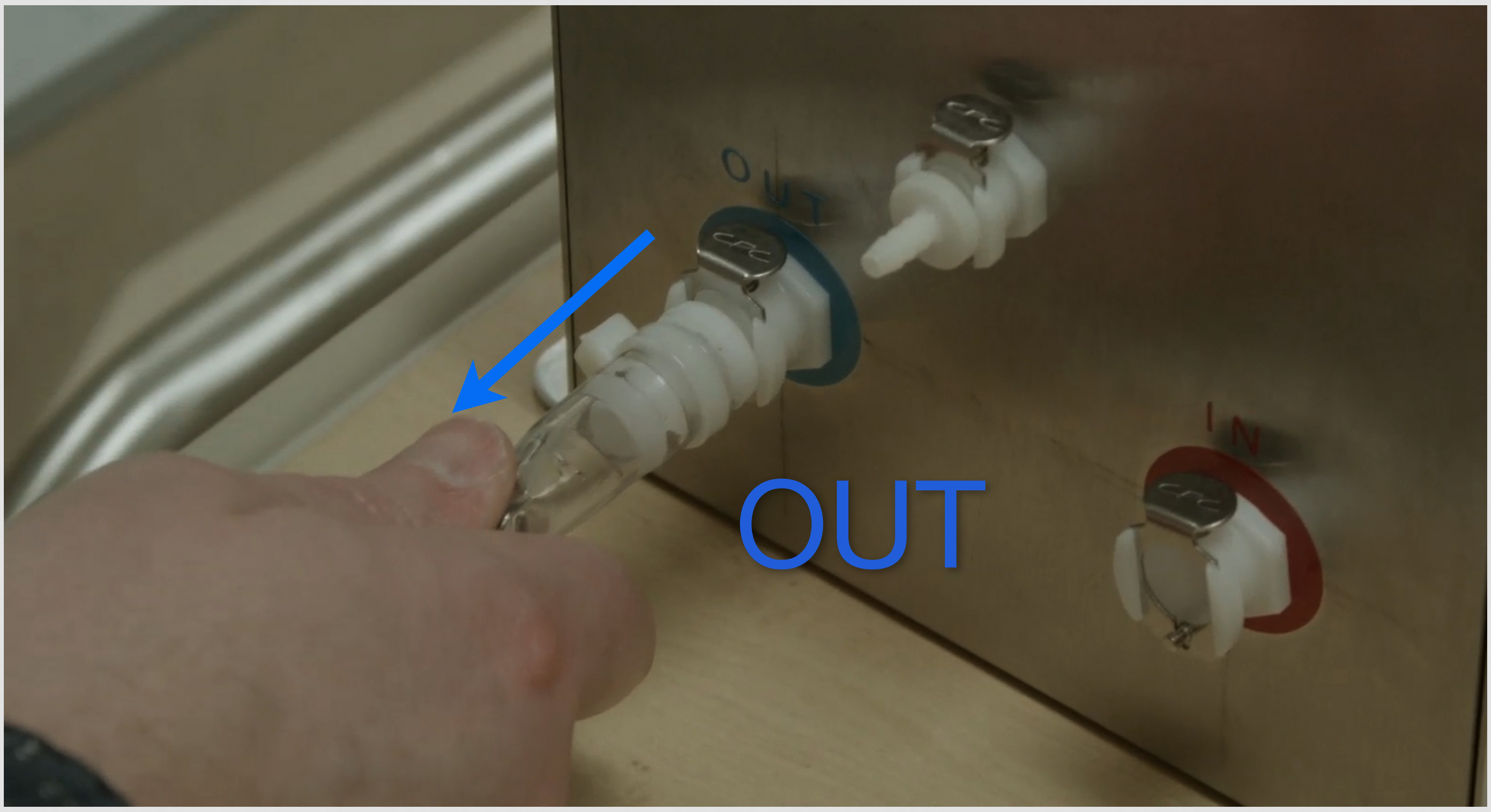


Figure 6: Connecting the venous OUT acetal connector to the OUT on your EigenFlow

Air Tubing Connection

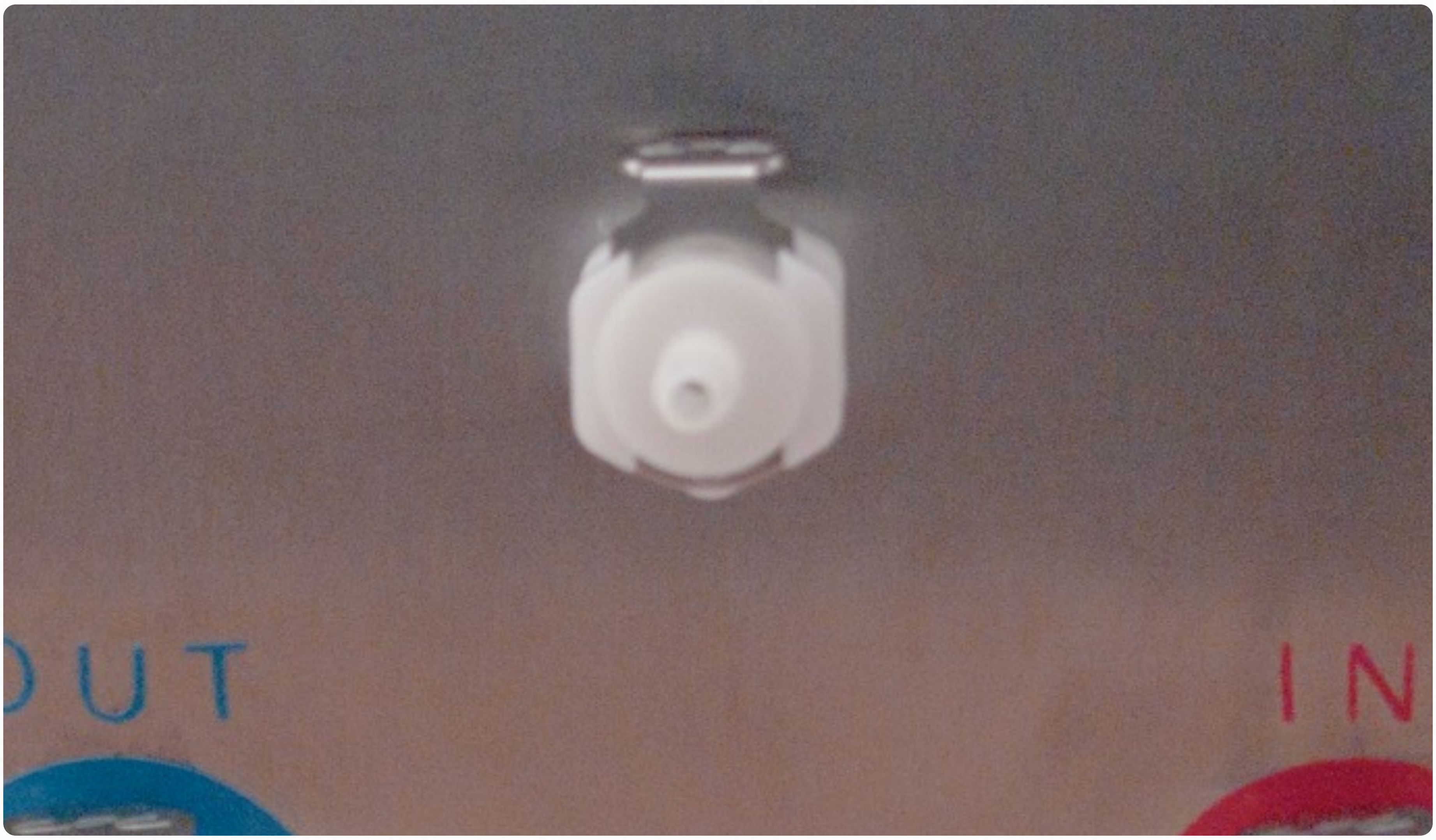


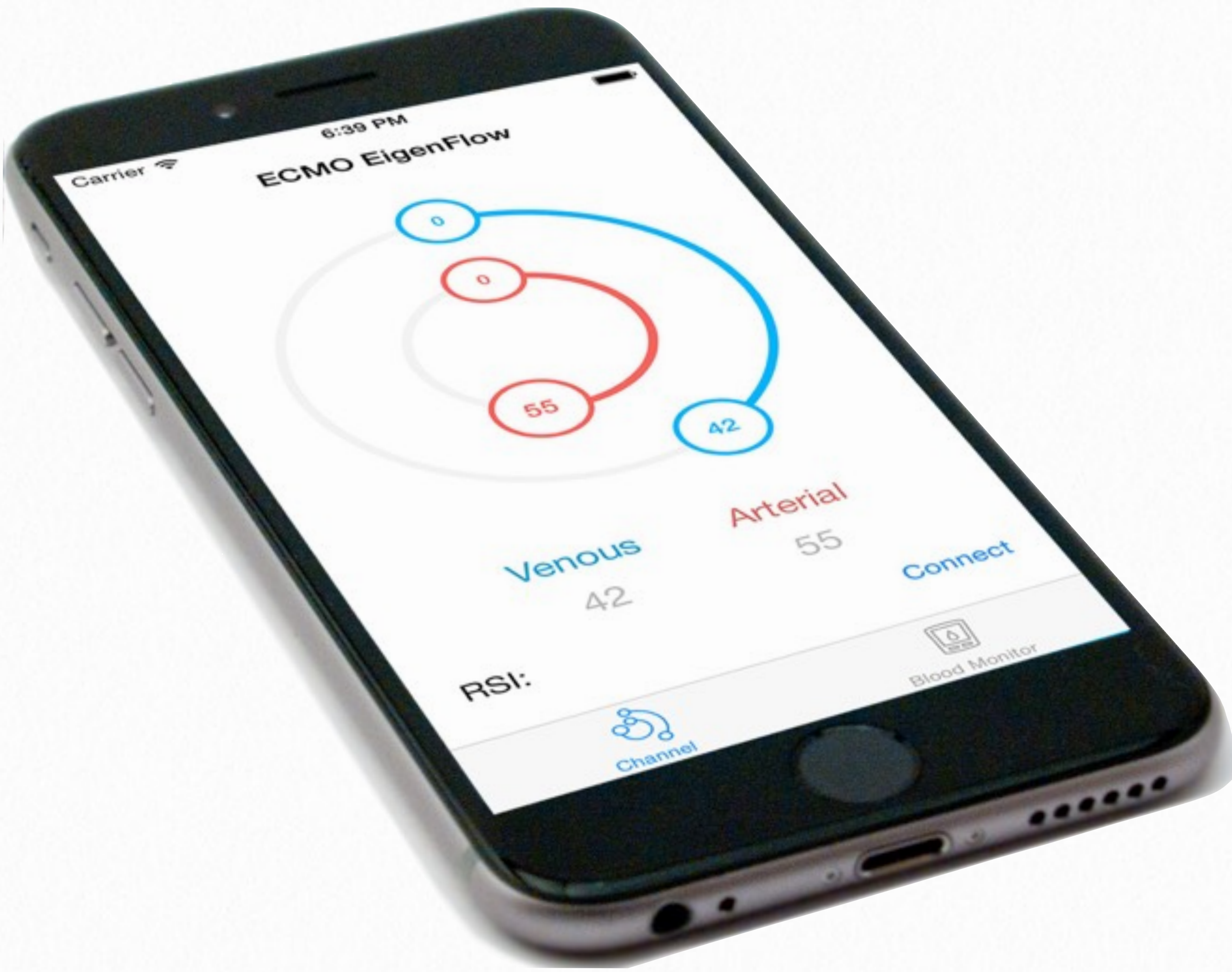
Figure 7: Connecting the green air tubing to the AIR connector on the back of your EigenFlow

To simulate an air entrainment/embolus scenario, connect the green air tubing to a luer lock along your ECMO circuit. and the acetal connector to the AIR connection on the back of your EigenFlow (Figure 7). If you connect the air tubing on the arterial side, you can simulate a rare but dangerous scenario when air emboli form can quickly move to the patient. If you connect the air tubing to the venous side, you can simulate the most common air entrainment/embolus scenarios.

Small air emboli will set off bubble sensors on the venous side and eventually will be filtered out in the oxygenator. Large air emboli will overload the oxygenator and shut down the pump to allow learners to practice pulling air out of the ECMO circuit. To learn more see the section “Air Entrainment” in the fourth chapter of “Example Scenarios” on page 19.

4

EigenFlow App



Thrombosis

Once EigenFlow is connected, launch the EigenFlow app on your iOS device. Inside the EigenFlow app there are three tabs at the bottom of the display for each component of the EigenFlow app: thrombosis, embolus, and blood monitor. The first screen is the Thrombosis tab (Figure 8). The thrombosis tab's main function is to control of obstruction in your ECMO circuit. There are a series of control valves inside your EigenFlow that can open and close to the amount of obstruction you want to create. To control this amount, two finger controlled circles can be changed to control how open and closed the valves inside your EigenFlow are.

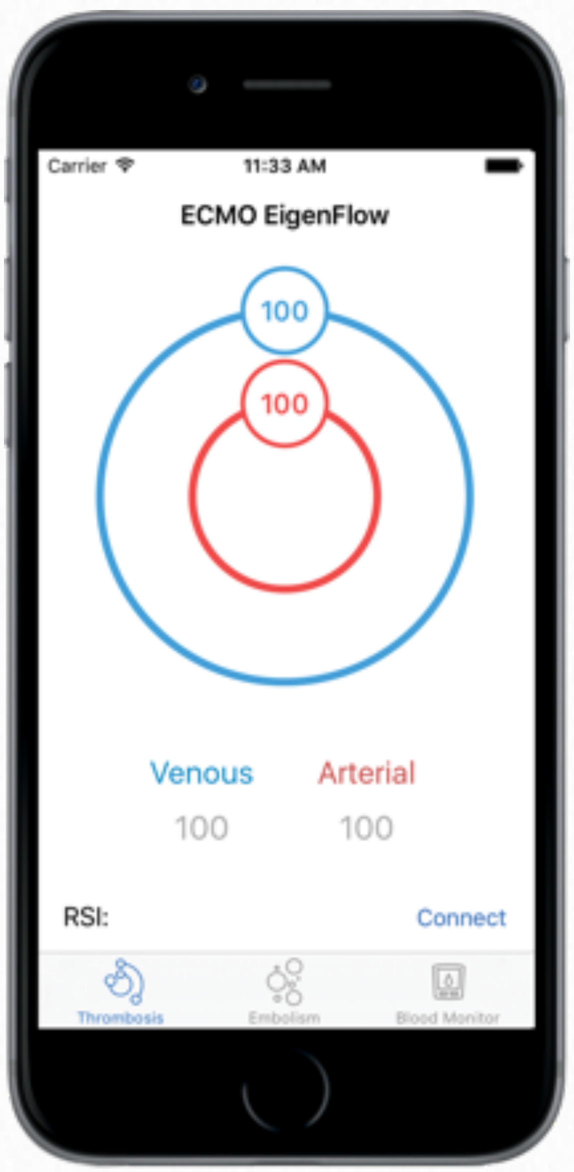


Figure 8: Open Thrombosis Tab

After priming your valves in step 6 in "Getting Started" on page 11, your valves will be set to 100 which sets the valves inside your EigenFlow to 100% open. When the valves are open, there will be no resistance added to the ECMO circuit (Figure 8). You'll notice that the two circles have two colors, red and blue or arterial and venous. These colors correlate to the acetal connectors on the front of your EigenFlow. To control the amount of resistance on the arterial or venous side of your ECMO circuit, simply move the colored circle to the value of resistance from 0 to 100. 0 represent a completely closed valve, 25 represents a 25% open valve (75% closed), 50 represent a 50% open valve (50% closed) and 100 represents a 100% open valve (Figure 8, 9, 10, 11). **Note: Resistance may not effect ECMO pressures until resistance is set to 25 or less.**

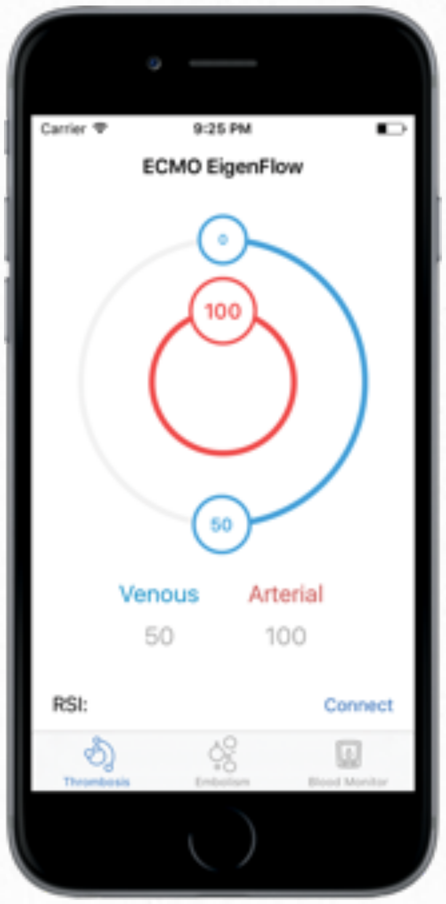


Figure 9: Venous 50% Open

Figure 10: Venous 25% Open

Figure 11: Venous Closed

Embolus

To inject an air embolus into your ECMO circuit select the embolus tab inside the EigenFlow app (Figure 12) and connect the green air tubing to your circuit as explained in the “Air Tubing Connection” on page 18. Three choices in air embolus sizes are available to select: small, medium, and large (Figure 12, 13, 14). Small will inject 8 mL of air, Medium will inject 25 cc of air, Large will inject 42 mL of air. Press the green “Start” to have your EigenFlow inject an air embolus into your circuit. (Figure 12).

Figure 12: Small Embolus

Figure 13: Medium Embolus

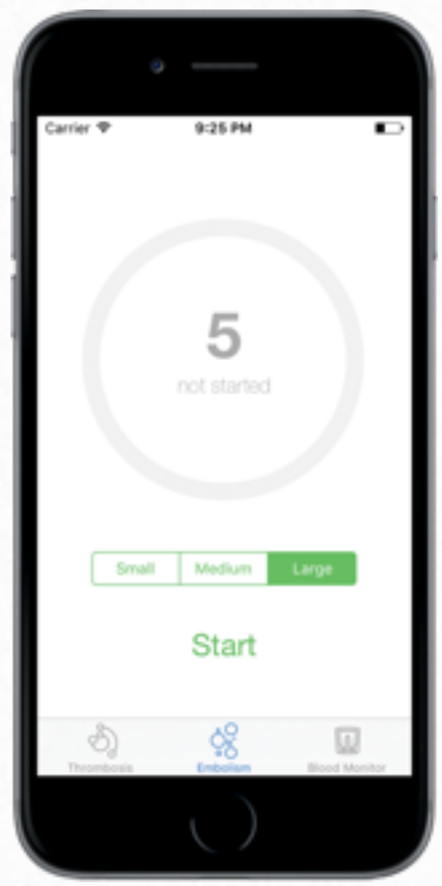


Figure 14: Large Embolus

Blood Monitor

The vital blood parameters displayed on the EigenFlow Lilliput LCD monitor can be changed by selecting the Blood Monitor tab inside your EigenFlow app. A list of all the blood parameters can be changed by selecting the parameter (Figure 15) and a numerical value of that parameter will be displayed (Figure 16). By selecting the number, a numerical keyboard will be displayed where the user can input what value they would like to change it to (Figure 17).

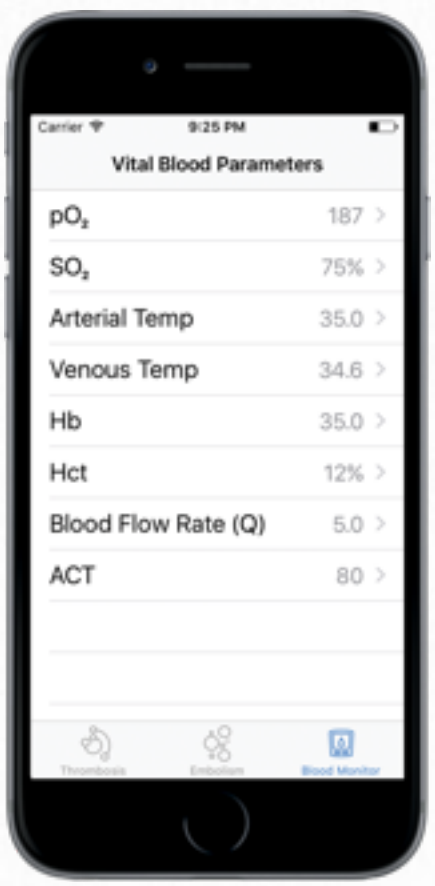


Figure 15: Vital Blood Parameter Menu

Figure 16: Selected pO2 Value

Figure 17: pO2 Value Change with numerical keyboard

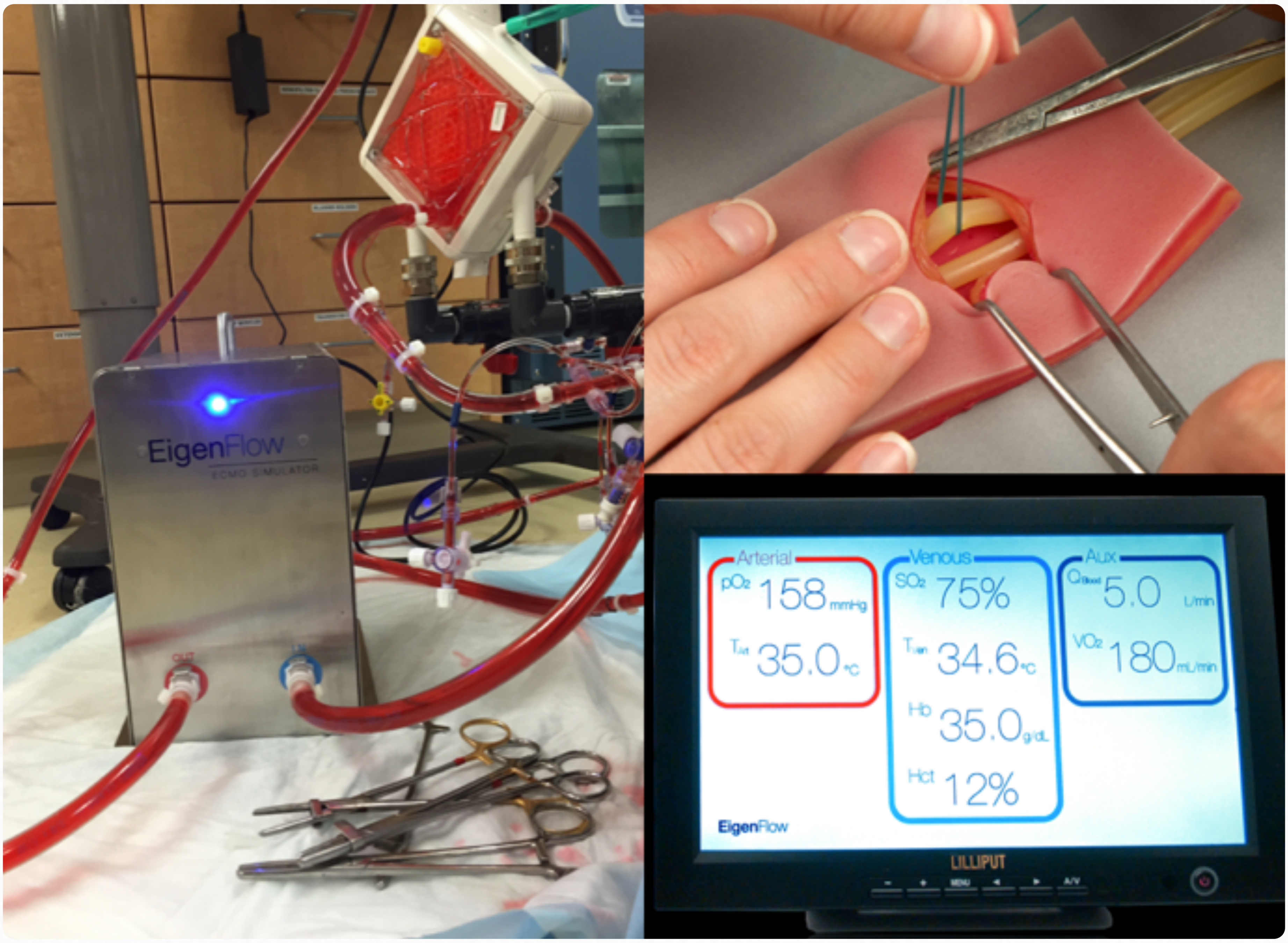
You can update the monitor with your new value by selecting it to update “Now” or at a specified trend value. For instance you can trend it to your inputted value over 10 seconds to 5 minutes (Figure 18 and 19). Start this trend by pressing “Done” at the top right hand of the app.

Figure 18: pO2 Value Change with trend to Now

Figure 19: pO2 Value Change with trend to 1 min

5

Clinical Scenarios



Enhance your simulation-based education with scenarios to provide authentic, intensive, interactive ECMO training without risk to real patients. We used methodologies pioneered by the aerospace industry and our experience developing a simulation-based training program in neonatal resuscitation to develop example scenarios in ECMO crisis management.

Included in this user manual are three sets of scenarios for both neonatal and adult simulations. These six scenarios are based on the ELSO guidelines and the paper "Simulating Extracorporeal Membrane Oxygenation Emergencies to Improve Human Performance. Part I: Methodologic and Technologic Innovations" by Anderson et al.

Orange badge represents newborn scenarios. Blue badge represents adult scenarios

History

A survey was conducted at the 19th Annual Children's National Medical Center ECMO Symposium to determine current methods for ECMO training. Using commercially available technology, Anderson et al, linked a neonatal manikin with a standard neonatal ECMO circuit primed with artificial blood. Both the manikin and circuit were placed in a simulated neonatal intensive care unit environment equipped with remotely controlled monitors, real medical equipment and human colleagues. Twenty-five healthcare professionals, all of whom care for patients on ECMO and who underwent traditional ECMO training in the prior year, participated in a series of simulated ECMO emergencies. At the conclusion of the program, subjects completed a questionnaire qualitatively comparing ECMO Sim with their previous traditional ECMO training experience [1].

The results of this experience reported that ECMO simulation engaged their intellect to a greater degree and better developed their technical, behavioral, and critical thinking skills. Active learning (eg, hands-on activities) comprised 78% of the total ECMO Sim program compared with 14% for traditional ECMO training ($P < 0.001$). Instructor-led lectures predominated in traditional ECMO training [1].

Oxygenator Clot

Background

2 month old with a viral myocarditis. You are on day 5 of the run. You have just started your shift. No mechanical problems have been encountered with the circuit, but the off going ECMO specialist was very tired and mentioned that there were some new clots in the oxygenator. Some of the morning lab results are now available.

Patient

ECMO	VV
Temp	37°C
HR	135 BPM
BP	72/38 (49)
RR	14
CVP	5
Sats	97%
SvO2	66% (EigenFlow Monitor)
SM	SaO2 100%
H/H	36% / 12 (EigenFlow Monitor)

ECMO Specialist Exam

Physical Exam = quiet. blood oozing from cannula site.

Breath Sounds = equal

Heart Sounds = normal

Abdomen = soft

Peripheral Refill = 3 sec. distal extremities cool.

Color Blood in Circuit Tubing = color differentiation seen

Oxygenator = clots seen

Sweep gas = 2.5 lpm,

FiO2 = 0.7

CXR: ordered, but tech is busy in the CVICU with a code

Chem: Sent. Results pending.

Heme: Plt ct 42K after transfusion, Fibrinogen 68K, decreased from 72K despite treatment with FFP

ACT: 225 with heparin gtt at 0.5ml/hr

State	Patient Status	Learner Action	Operator Triggers
Initial	**P1** 0 **P2** 149 **P3** -2 **P4** 145		Set Venous Thrombosis = **100 (OPEN)**
Blood Clot	**P1** -9 **P2** **281** **P3** -10 **P4** 149	• Recognize abnormal labs • Recognize trend in post membrane ABG PCO2 and PO2 • Adjust sweep gases • Calls for help • Circuit check • Check oxygenator for clots • Recognize abnormal trans-membrane gradient • Adjusts heparin rate (lower) • Gives blood products (platelets, FFP, cryo) • Identify oxygenator failure-with plan of action for rapid change out	Increase HR to **150** Decrease O_2 Sats to **87%** Decrease BP to **45/23** Set Venous Thrombosis = **25 then 0 over 2 minutes**
Resolved	**P1** 0 **P2** 149 **P3** -2 **P4** 145	**Must complete in 5 minutes**	Set Venous Thrombosis = **100 (OPEN)** Decrease HR to **135** Increase O_2 Sats to **97%** Increase BP to **72/38** Increase SvO_2 to **75%**

Air Entrainment

Background

1 month old with H1N1 pneumonia and myocarditis. You are on day 2 of the run. You have just started your shift. No mechanical problems have been encountered with the circuit. Some of the morning lab results are now available.

Patient

ECMO	VA
Temp	37°C
HR	135 BPM
BP	72/38 (49)
RR	14
CVP	5
Sats	97%
SvO2	79% (EigenFlow Monitor)
SM	SaO2 100%
H/H	39% / 12 (EigenFlow Monitor)

ECMO Specialist Exam

Physical Exam = quiet. No spontaneous movements. Mottled.

Breath Sounds = equal

Heart Sounds = normal

Abdomen = soft

Peripheral Refill = 3 sec. distal extremities cool.

Color Blood in Circuit Tubing = equal

Oxygenator = normal

Sweep gas = 2.5 lpm,

FiO2 = 0.7

CXR: ask for reason, normal

Chem: Sent. Results pending.

Heme: Plt ct 42K after transfusion, Fibrinogen 68K, decreased from 72K despite treatment with FFP

ACT: 225 with heparin gtt at 0.5ml/hr

State	Patient Status	Learner Action	Operator Triggers
Initial	**P1** 0 **P2** 130 **P3** -11 **P4** 120		
Air Embolus	**P1** -9 **P2** 130 **P3** -10 **P4** 149	• Realize Pump Off • Clamps off A-B-V • Calls for help • Emergency vent settings • Check oxygenator • Check connections: venous & arterial • Start CPR	In Embolism tab Select **"Medium"** and press **"Start"** **If pump stops** Increase HR to **150** Decrease O_2 Sats to **87%** Decrease BP to **45/23**
Resolved	**P1** 0 **P2** 149 **P3** -2 **P4** 145	**Must complete in 5 minutes**	If pump starts Decrease HR to **135** Increase O_2 Sats to **97%** Increase BP to **72/38** Increase SvO_2 to **75%**

High Post-Oxygenator Pressure

Background

A 33 year old man, weighing 80 kgs, who has been transferred to your unit for Veno-Venous ECMO. He was admitted with severe respiratory failure with increasing respiratory distress, fever, and sputum cultures with grew a methicillin-sensitive staphylococcus aureus.

Patient

ECMO	VV
Temp	38.0ºC
HR	110 BPM
BP	80/43 (55)
RR	14
CVP	5
Sats	97%
SvO2	75% (EigenFlow Monitor)
SM	SaO2 74%
H/H	36% / 12 (EigenFlow Monitor)

ECMO Specialist Exam

Physical Exam = sedated. No spontaneous movement.

Breath Sounds = equal

Heart Sounds = normal

Abdomen = soft

Peripheral Refill = 3 sec. distal extremities cool.

Color Blood in Circuit Tubing = No color differentiation seen

Sweep gas = 8 lpm,

FiO2 = 0.7

CXR: normal

Chem: Sent. Results pending.

ACT: 180 with heparin gtt at 0.5ml/hr

State	Patient Status	Learner Action	Operator Triggers
Initial	**P1** 107 **P2** 110 3.5 **Lpm**		Set Arterial Thrombosis = **100 (OPEN)** Set PaO_2 to **47 mm Hg** Set $PaCO_2$ to **42 mm Hg**
Obstruct Post Oxygenator	**P1** 140 **P2** 112 0.5 **Lpm**	• Orders chest x-ray • Recognize flow rate has decreased • Circuit Check • Calls for help • Emergency vent settings • Check oxygenator • Check connections: venous & arterial **Inappropriate Actions** • Adjust arterial cannula • Calls Surgeon	Set Arterial Thrombosis = **15** **Over 5 mins** Increase HR to **140** with Ecotopy Decrease O_2 Sats to **87%** Decrease PaO_2 to **20**
Resolved	**P1** 107 **P2** 112 3.5 **Lpm**	**Must complete in 5 minutes**	Set Arterial Thrombosis = **100 (OPEN)** Decrease HR to **135** Increase O_2 Sats to **97%** Increase BP to **72/38** Increase SvO_2 to **75%**

High Pre-Oxygenator Pressure

Background

A 33 year old man, weighing 80 kgs, who has been transferred to your unit for Veno-Venous ECMO. He was admitted with severe respiratory failure with increasing respiratory distress, fever, and sputum cultures with grew a methicillin-sensitive staphylococcus aureus.

Patient

ECMO	VV
Temp	38.0ºC
HR	110 BPM
BP	80/43 (55)
RR	14
CVP	5
Sats	97%
SvO2	75% (EigenFlow Monitor)
SM	SaO2 74%
H/H	36% / 12 (EigenFlow Monitor)

ECMO Specialist Exam

Physical Exam = sedated. No spontaneous movement.

Breath Sounds = equal

Heart Sounds = normal

Abdomen = soft

Peripheral Refill = 3 sec. distal extremities cool.

Color Blood in Circuit Tubing = No color differentiation seen

Sweep gas = 8 lpm,

FiO2 = 0.7

CXR: normal

Chem: Sent. Results pending.

ACT: 180 with heparin gtt at 0.5ml/hr

State	Patient Status	Learner Action	Operator Triggers
Initial	**P1** 107 **P2** 110 3.5 **Lpm**		Set Venous Thrombosis = **100 (OPEN)** Set PaO_2 to **47 mm Hg** Set $PaCO_2$ to **42 mm Hg**
Obstruct Post Oxygenator	**P1** 12 **P2** 112 0.5 **Lpm**	• Orders chest x-ray • Recognize flow rate has decreased • Circuit Check • Calls for help • Emergency vent settings • Check oxygenator • Check connections: venous & arterial **Inappropriate Actions** • Adjust venous cannula • Calls Surgeon	Set Venous Thrombosis = **15** **Over 5 mins** Increase HR to **140** with Ecotopy Decrease O_2 Sats to **87%** Decrease $PaCO_2$ to **20** Increase PaO_2 to **80**
Resolved	**P1** 107 **P2** 112 3.5 **Lpm**	**Must complete in 5 minutes**	Set Venous Thrombosis = **100 (OPEN)** Decrease HR to **135** Increase O_2 Sats to **97%** Increase BP to **72/38** Increase SvO_2 to **75%**

VV ECMO Preparation

Background

A 33 year old man, weighing 80 kgs, who has been transferred to your unit for Veno-Venous ECMO. He was admitted with severe respiratory failure with increasing respiratory distress, fever, and sputum cultures with grew a methicillin-sensitive staphylococcus aureus.

Patient

ECMO	VV
Temp	37.0°C
HR	110 BPM
BP	110/56 (55)
RR	21
CVP	8
Sats	85%
SvO2	75% (EigenFlow Monitor)
SM	SaO2 82%
H/H	36% / 12 (EigenFlow Monitor)

ECMO Specialist Exam

Physical Exam = sedated. No spontaneous movement.

Breath Sounds = equal

Heart Sounds = normal

Abdomen = soft

Peripheral Refill = 3 sec. distal extremities cool.

Color Blood in Circuit Tubing = No color differentiation seen

Sweep gas = 8 lpm,

FiO2 = 0.7

CXR: normal

ACT: 120

State	Inappropriate Action	Appropriate Action	Operator Triggers
Initial			
ECMO Circuit Hookup	• Circuit not primed • Circuit has air emboli • No Pre-ECMO checklist • Incorrect Heparin dose calculated	• Circuit primed • Circuit free of air emboli • Pre-ECMO checklist • Correct Heparin dose calculated	**Appropriate Action** ACT = 320 **Inappropriate Action** **Increased Heparin** ACT = 500 **Decreased Heparin** ACT = 150
Certified For Therapy		**Must complete within 3 minutes of circuit hookup** • ACT checked with surgeon	**Appropriate Action** ACT = 320 **Inappropriate Action** ACT = 140 Decrease O_2 Sats to **65%**

Venous Air Entrainment

Background

55-yr-old male with an AMI and is in cardiogenic shock. You are on day 2 of the run. You have just started your shift. No mechanical problems have been encountered with the circuit.

Patient

ECMO	VA
Temp	36.8°C
HR	102 BPM
BP	104/57 (49)
RR	20
CVP	8
Sats	96%
SvO2	70% (EigenFlow Monitor)
SM	SaO2 100%
H/H	10% / 26 (EigenFlow Monitor)

ECMO Specialist Exam

Physical Exam = quiet. No spontaneous movements. Mottled.

Breath Sounds = equal

Heart Sounds = normal

Abdomen = soft

Peripheral Refill = 3 sec. distal extremities cool.

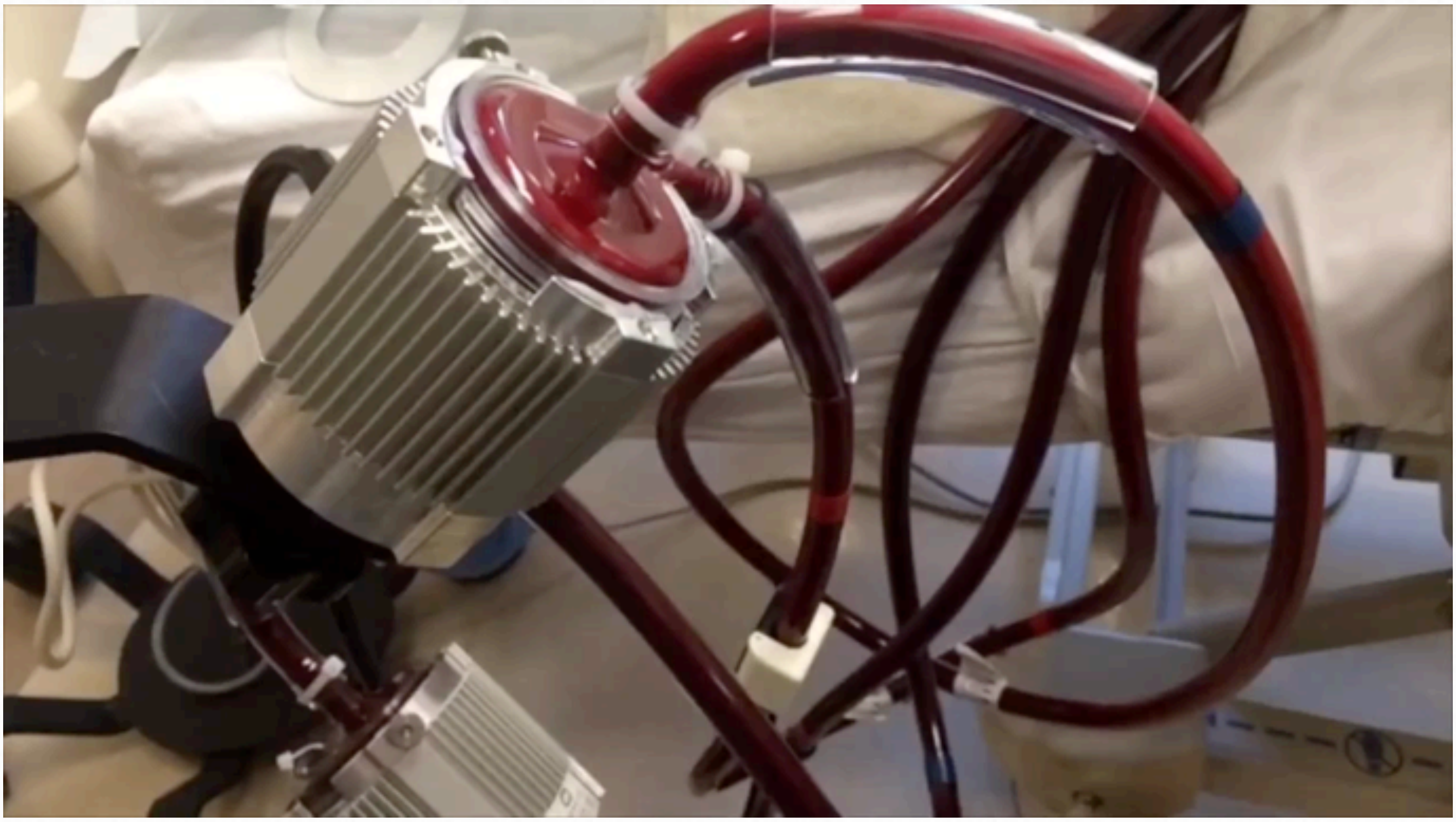
Color Blood in Circuit Tubing = equal

Oxygenator = normal

Sweep gas = 8 lpm, **FiO2** = 70%, **CXR** = normal, **ACT** = 190

State	Inappropriate Learner Action	Appropriate Learner Action	Operator Triggers
Air Embolus	• Does not turn pump off • Does not clamp off • Does not increase vent settings • Does not call for help	• Turns pump off • Clamps off A-B-V • Calls for help • Emergency vent settings set to 100% oxygen • Places patient in Trendelenburg position • Check oxygenator • Check connections: venous & arterial • Start CPR if necessary • Aspirate venous air • Run through bridge	In Embolism tab Select **"Large"** and press **"Start"** **Appropriate** Increase HR to **110** Decrease O_2 Sats to **93%** Increase CVP to **10** Decrease SvO_2 to **55%** **Inappropriate** Increase HR to **140** Decrease O_2 Sats to **83%** Decrease BP to **73/42** Decrease SvO_2 to **48%**
More Air Emboli	• Does not turn pump off • Does not clamp off • Does not increase vent settings • Does not call for help **Inappropriate** Decrease HR to **155** Decrease BP to **55/35** Decrease SvO_2 to **55%**	• Move air to nearest stopcock • Remove air • Back on ECMO • Flush bridge • Consider Blood	In Embolism tab Select **"Small"** and press **"Start"** **Appropriate** Decrease HR to **92** Increase O_2 Sats to **98%** Decrease CVP to **9** Increase BP to **114/62** Decrease ACT to **170** Increase SvO_2 to **70%** Decrease HCT to **22** **More Inappropriate** Decrease HR to **33** Decrease O_2 Sats to **40%**
Resolution		**Must complete in 5 minutes**	**Inappropriate** HR to **Asystole**

ECMO Pump Chatter



A common problem for ECMO Specialists is erratic pump flow. When the maximum flow rate is exceeded in a patient, the negative pressure in the venous system causes the venous vessels to collapse, stopping blood flow temporarily. This intermittent stopping and starting is known as pump chatter. If your ECMO pump is a centrifugal pump, you can simulate pump chatter using EigenFlow. Simply connect the blue channel of your EigenFlow to the venous side of your ECMO pump before the inlet of the pump (Figure 1). Once connected follow the steps in Chapter 2: “Getting Started” to startup your EigenFlow. Next, select the thrombosis tab in the EigenFlow app and change the venous channel value from “100” to “25” This will initiate pump chatter (Figure 8, 9)

Pump chatter left untreated can damage the inferior vena cava. The fastest way for

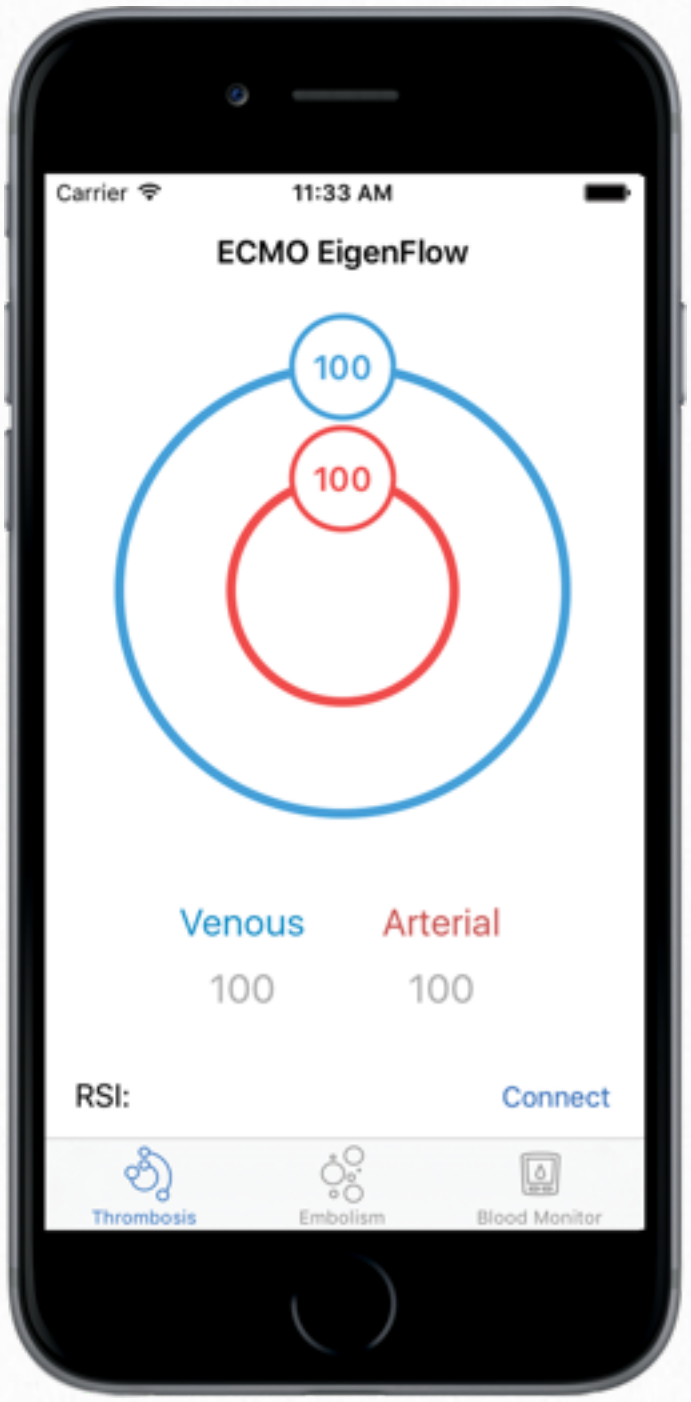


Figure 8: Venous Valves 100% Open

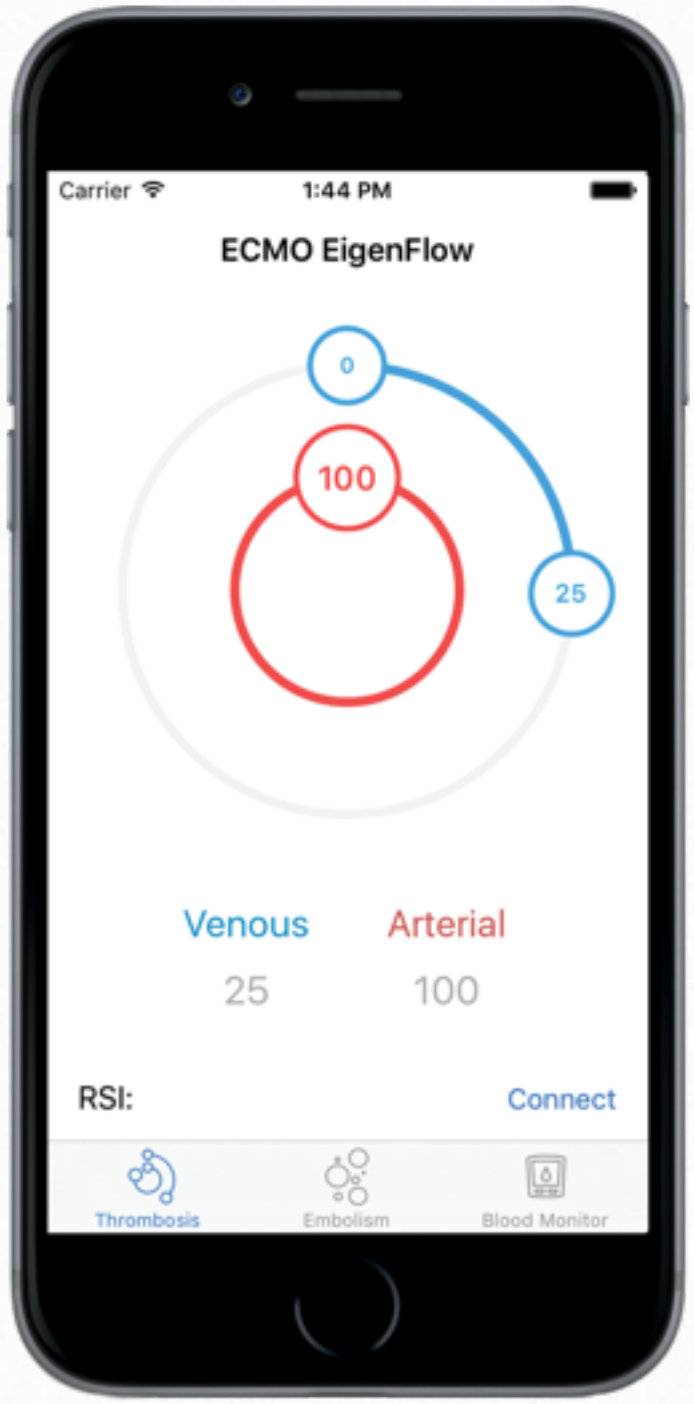


Figure 9: Venous Valves 25% Open

the learner to stop pump chatter is to reduce the pump RPM and blood flow rate, but this may not provide enough blood and gas exchange support. If the patient you are simulating requires higher blood flows, the learner can be expected to make these interventions: correct hypovolemia, patient positioning, cannula kinking, upsize cannulas, inspect tubing and cannula for kinking, and ultra for presence of any thrombus/clotting.

If you are simulating a patient that requires you to use lower blood flows because of chatter, the learner should increase the patient's oxygenation or hematocrit levels to provide additional oxygen carrying capability.

6

Preventative Maintenance

**“The wounded surgeon plies the steel
That questions the distempered part;
Beneath the bleeding hands we feel
The sharp compassion of the healer's art”**

– T.S. Elliot

EigenFlow is made of marine grade stainless steel that will resist corrosion when used with aqueous saline solutions

EigenFlow preventative maintenance requires only one step to prevent corrosion to the EigenFlow valves. Before storing EigenFlow, you'll need to flush the valves using distilled water, isopropyl alcohol, or a mixture of both. First, set your valves to 100 (OPEN) and turn off your EigenFlow. Next, connect your flush tubing to the arterial IN and venous IN and poor the flush solution through the valves and into a sink/basin to collect your fluid.