ECMO: Indications, management and troubleshooting

Kunal Kotkar, MD

Department of surgery

Division of Cardiothoracic surgery

BARNES-JEWISH Hospital BJC HealthCare

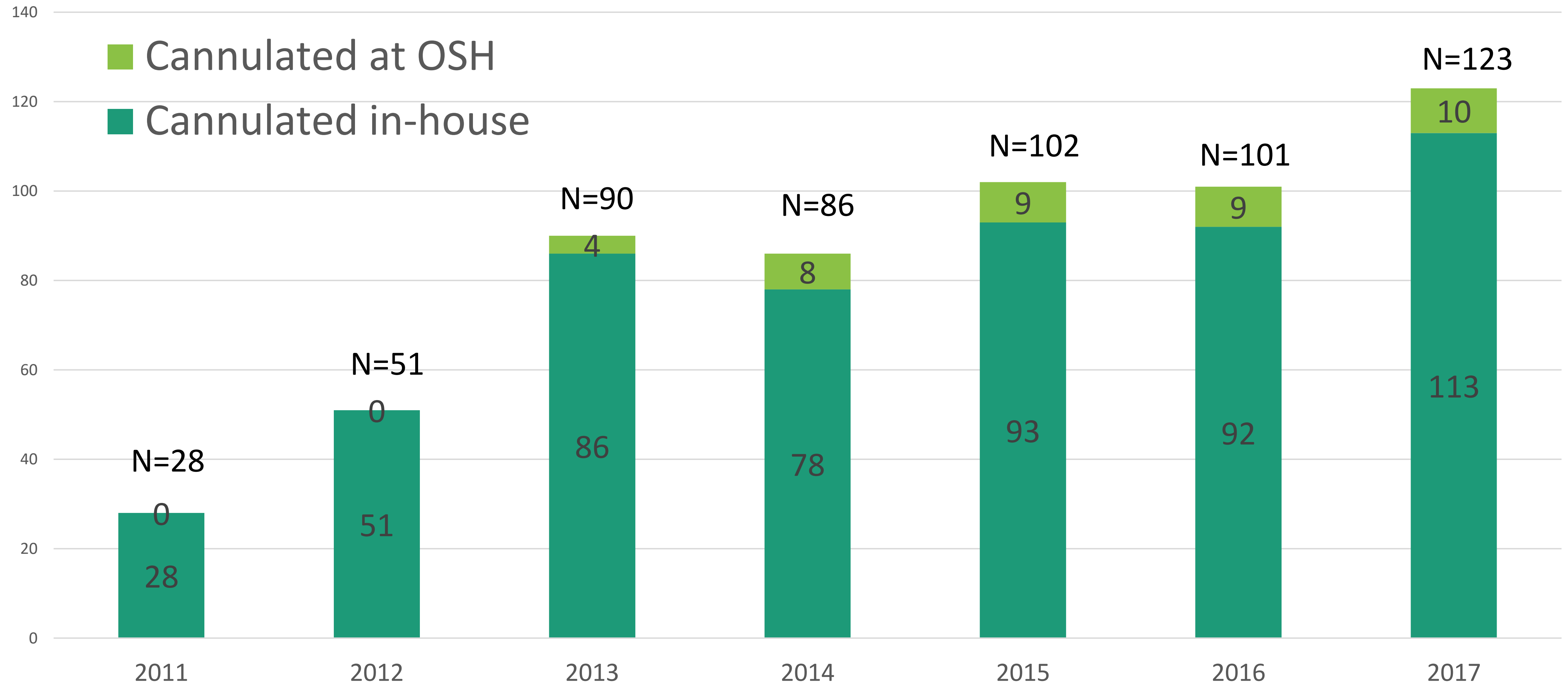
Washington University in St. Louis School of Medicine

ECMO

- ECLS is the use of mechanical devices to temporarily (days to months) support heart or lung function (partially or totally) during cardiopulmonary failure, leading to organ recovery or replacement

- Evolution from cardiopulmonary bypass

ECMO Cannulation



Indications

Respiratory failure

- ALI/ARDS
- Aspiration
- Pneumonia
- Asthma
- Post lung transplant
- Lung contusion

Cardiac Failure

- Acute coronary syndrome
- Myocarditis
- Post cardiac arrest
- Pulmonary embolus
- Drug overdose
- Post cardiac surgery
- Bridge to transplant
- Post heart transplant

Indication: Clinical condition

- Circulatory failure (CI<2.2)
- Severe acidosis (elevated lactate)
- Other organ damage(Liver enzymes, creatinine)
- Maxed out inotropic/vasopressor support
  - Epi 0.2mcg/kg/min, Norepi 0.2 mcg/kg/min etc
- Worsening ventilator setup, prone, bilevel, FIO2 90%..
- Unable to come off CPB
- Pt is on temporary devices(Impella, IABP etc)

Current Pharmacology & Devices

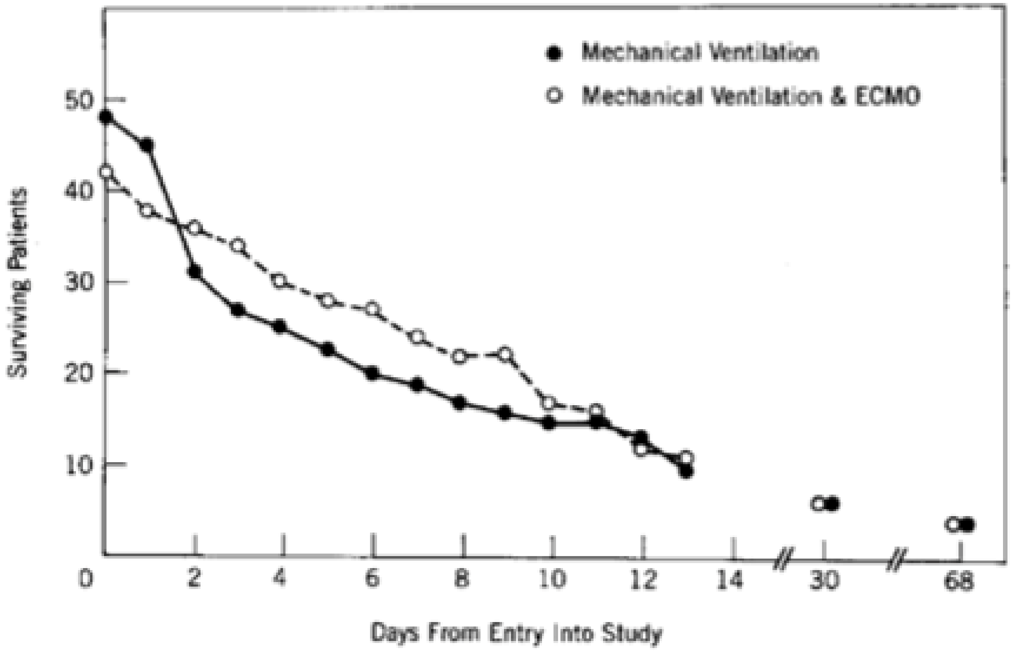
	Inotropes	IABP	ECMO	Tandem-Heart	Impella	LVAD
Advantages						
Flow (L/min.)	<0.5	0.5	2-6	3.5	2.5 - 5.0	3-6
Coronary Perfusion	↑	↑↑	-	-	↑↑	↑↑
LVEDP	↑	↓	↑↑↑	↓↓	↓↓↓	↓↓↓↓
Limitations						
Arrhythmia	+++	-	-	-	-	-
Stroke	-	++	++	+	+	+++
Limb ischemia	N.A	+	+++	++	+	N.A
Bleeding	N.A	++	++++	+++	+ / ++	++++
Cost	$	$	$$$	$$$	$$$	$$$$$

Indications for ECLS in Adult respiratory failure:

1. In hypoxic respiratory failure due to any cause (primary or secondary) ECLS should be considered when the risk of mortality is 50% or greater, and is indicated when the risk of mortality is 80% or greater.
   a. 50% mortality risk is associated with a $PaO_2/FiO_2 < 150$ on $FiO_2 > 90\%$ and/or Murray score 2-3.
   b. 80% mortality risk is associated with a $PaO_2/FiO_2 < 100$ on $FiO_2 > 90\%$ and/or Murray score 3-4 despite optimal care for 6 hours or more.
2. CO_2 retention on mechanical ventilation despite high Pplat (>30 cm H_2O)
3. Severe air leak syndromes
4. Need for intubation in a patient on lung transplant list
5. Immediate cardiac or respiratory collapse (PE, blocked airway, unresponsive to optimal care)

NIH trial

- 1979
- 90 patients
  - 48 MV
  - 42 MV + ECMO
- 8 survivors.
  - 4 in each group.
- Conclusion: no mortality benefit.



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 Lancet 2009; 374: 1351–63

- Lancet 2009

- 180 pts, age 18-65 years, Murray score >3 or pH <7.2
- Randomization to ECMO vs Conventional Ventilation
- Exclusion: peak pressures >30

The Murray Lung Injury Score.

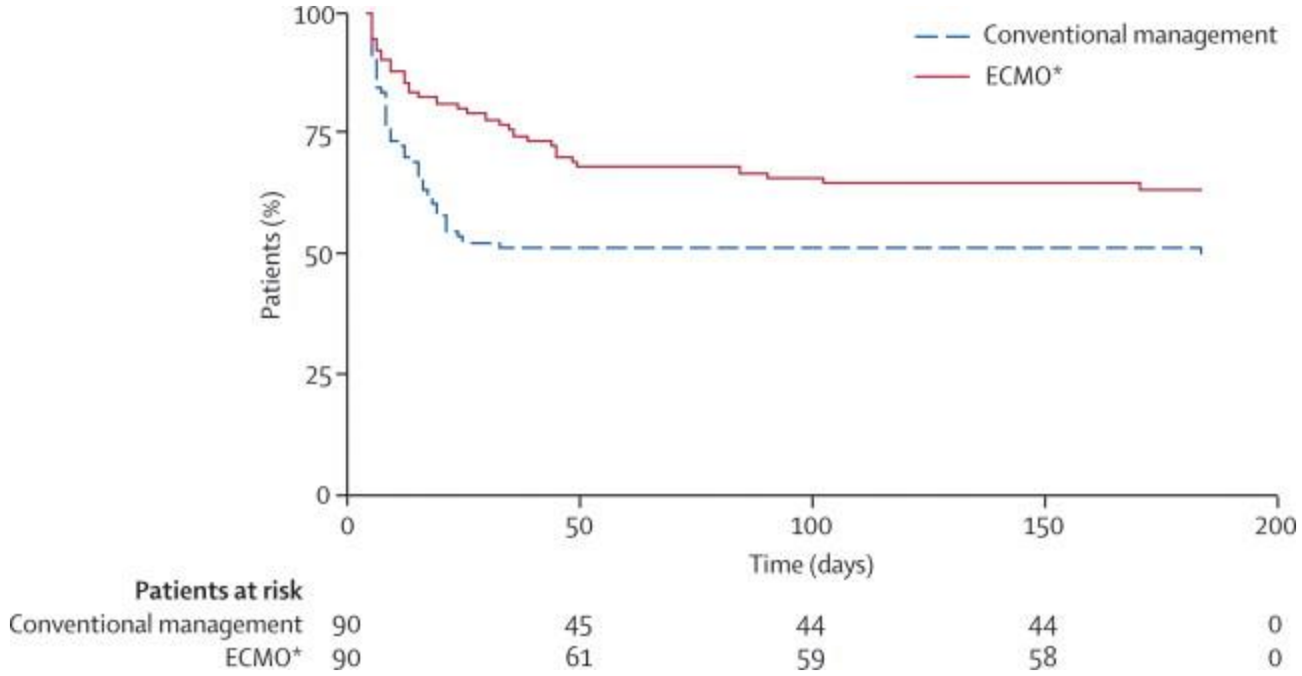
The lung injury score (Murray score)[14]		
1. Chest roentgenogram score		
No alveolar consolidation		0
Alveolar consolidation confined to 1 quadrant		1
Alveolar consolidation confined to 2 quadrant		2
Alveolar consolidation confined to 3 quadrant		3
Alveolar consolidation in all 4 quadrant		4
2. Hypoxemia score		
PaO_2/FiO_2	>300	0
PaO_2/FiO_2	225–299	1
PaO_2/FiO_2	175–224	2
PaO_2/FiO_2	100–174	3
PaO_2/FiO_2	≤ 100	4
3.PEEP score (when ventilated)		
PEEP	≤ 5 cm H_2O	0
PEEP	6–8 cm H_2O	1
PEEP	9–11 cm H_2O	2
PEEP	12–14 cm H_2O	3
PEEP	> 15 cm H_2O	4
4. Respiratory system compliance score (when available)		
Compliance	>80 ml/cmH_2O	0
Compliance	60–79 ml/cmH_2O	1
Compliance	40–59 ml/cmH_2O	2
Compliance	20–39 ml/cmH_2O	3
Compliance	< 19 ml/cmH_2O	4

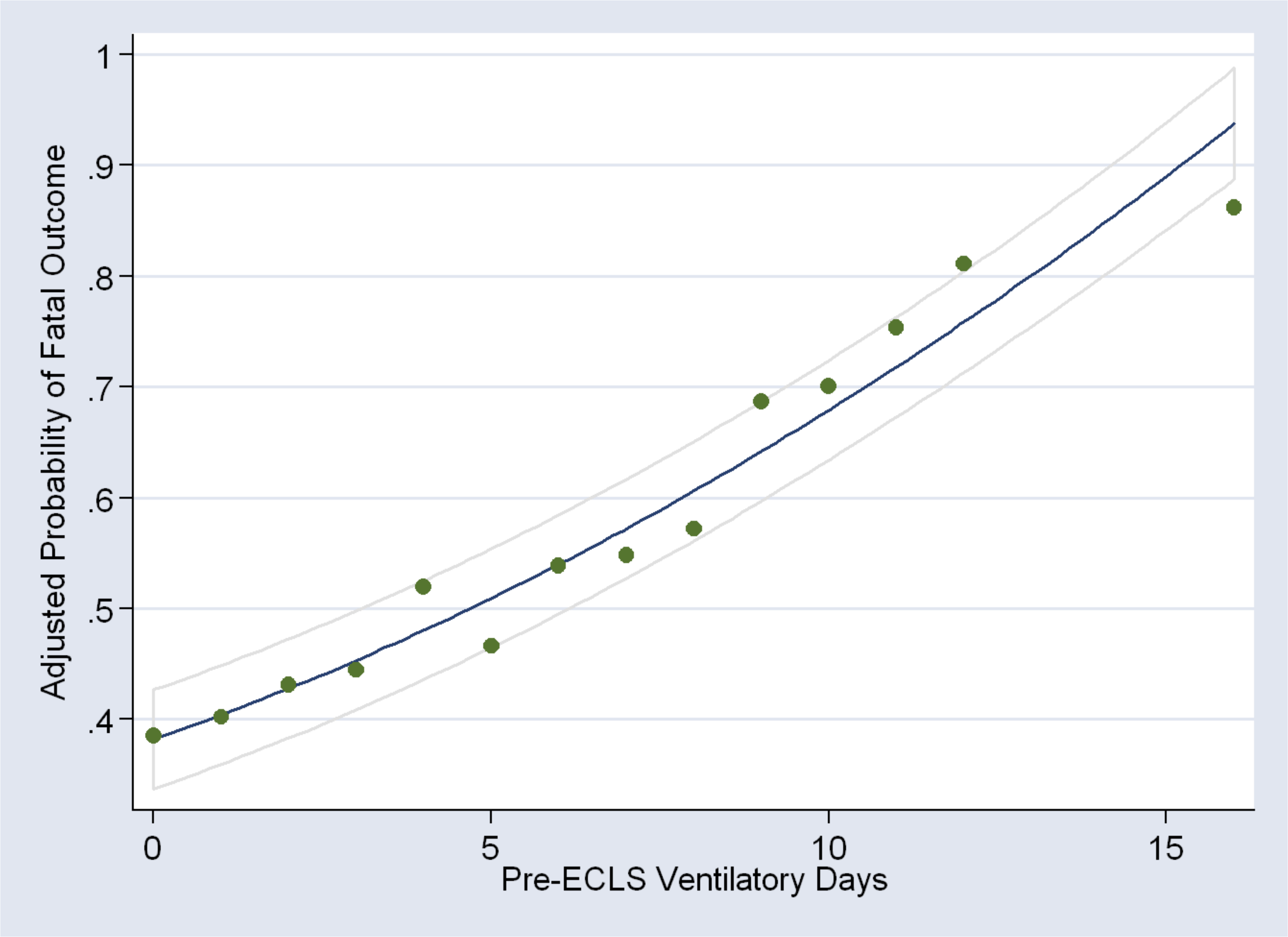
The final score is calculated by the addition of the component parts.

Score 0= no lung injury; 1–2.5 = mild to moderate lung injury

>2.5= severe lung injury

- 63% ECMO referral arm
- 47% Conventional





1
.9
.8
.7
.6
.5
.4
Adjusted Probability of Fatal Outcome
0
5
10
15
Pre-ECLS Ventilatory Days

Contraindication : Adult respiratory failure:

There are no absolute contraindications to ECLS, as each patient is considered individually with respect to risks and benefits. There are conditions, however, that are associated with a poor outcome despite ECLS, and can be considered relative contraindications

1. Mechanical ventilation at high settings (FiO2 > .9, P-plat > 30) for 7 days or more
2. Major pharmacologic immunosuppression (absolute neutrophil count<400/mm3)
3. CNS hemorrhage that is recent or expanding
4. Non recoverable co-morbidity such as major CNS damage or terminal malignancy
5. Age: no specific age contraindication but consider increasing risk with increasing age

Contraindications

Absolute Contraindications

- Severe irreversible neurological condition
- Encephalopathy
- Cirrhosis with ascites
- History of variceal bleeding
- Moderate-severe chronic lung disease
- Terminal malignancy

Absolute Contraindications to Veno-Venous ECMO

- Severe left ventricular failure EF <25%
- Cardiac arrest

Absolute Contraindications to Veno-Arterial ECMO

- Aortic dissection
- Severe aortic regurgitation

Contraindications

Relative Contraindications

- Age >65
- Multiple trauma with uncontrolled hemorrhage
- Multi-organ failure

Relative Contraindication to Veno-Venous ECMO

- High pressure / high FiO2 IPPV for >1 week

Relative Contraindication to Veno-Arterial ECMO

- Severe peripheral vascular disease

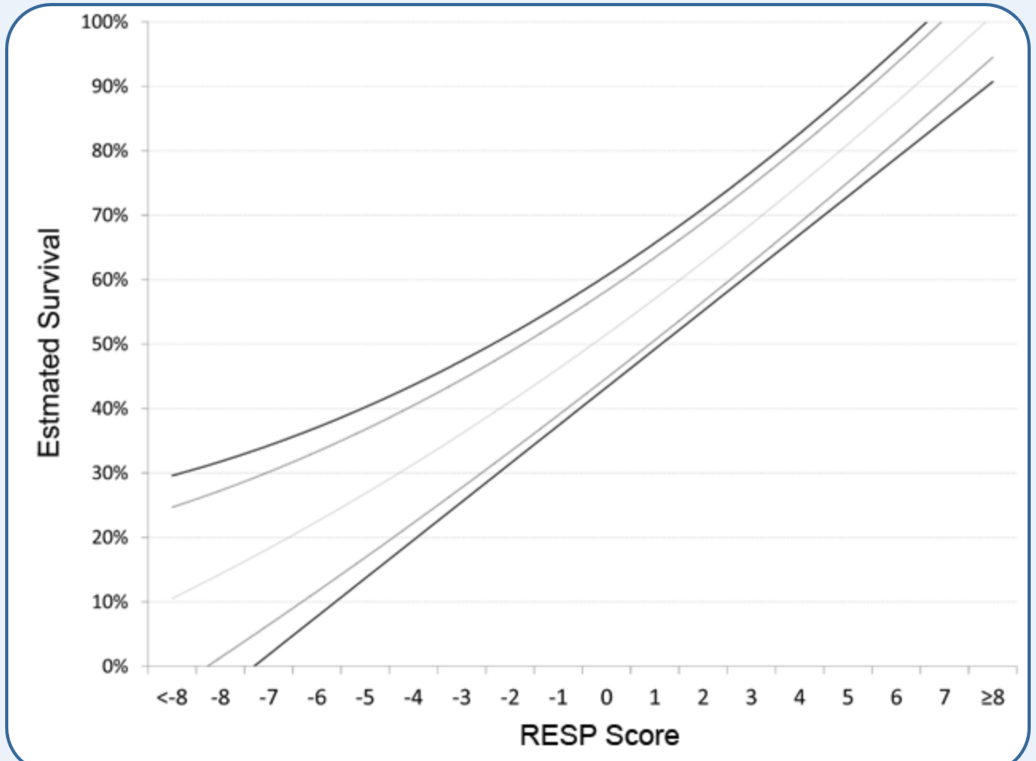
ELSO takes no responsibility for accuracy or application of calculations generated or for the use of these values.

SCORE	POPULATION	#VARIABLES	MODEL ROC	DEVELOPMENT DATASET YEAR	EXTERNAL VALIDATION	WEBSITE	CITATION
PIPER	Neonatal Respiratory Failure	8	0.74 (continuous); 0.73 (binned)	2000 - 2010	No	PIPER Score	Maul T et al; ASAIO Journal 2016; 62: 584 - 590 td
NEO-RESCUERS	Neonatal Respiratory Failure	10	0.78	2008 - 2013	No	http://www.neo-rescuers.com	Barbaro R et al; J Pediatr. 2016 Jun;173:56-61
PED-RESCUERS	Pediatric Respiratory Failure	13	0.69	2009 - 2014	No	http://www.ped-rescuers.com	Barbaro R et al; Intensive Care Med. 2016 May;42(5):879-88
P-PREP	Pediatric Respiratory Failure	6	0.69	2001 - 2013	Yes	http://www.picuscientist.org/pprep	Bailly DK et al; Crit Care Med 2016; epublished
RESP	Adult Respiratory Failure	12	0.74	2000 - 2012	Yes	http://www.respscore.com	Schmidt M et al; Am J Respir Crit Care Med 2013; 189: 1374 - 1382
SAVE	Adult Cardiogenic Shock	11	0.68	2003 - 2013	Yes	http://www.save-score.com	Schmidt M et al; Eur Heart J. 2015 Sep 1;36(33):2246-56
CDH Pre-ECMO	Neonates with Congenital Diaphragmatic Hernia	12	0.65	2000-2015	No	https://www.choc.org/ecmocalc/	Guner et al; ASAIO Journal; Nov 2017
CDH On-ECMO		22	0.73				

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.



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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

Table 3: The RESP Score at ECMO Initiation

Parameter	Score
Age, yr	
18 to 49	0
50 to 59	−2
⩾60	−3
Immunocompromised status*	−2
Mechanical ventilation prior to initiation of ECMO	
<48 h	3
48 h to 7 d	1
>7 d	0
Acute respiratory diagnosis group (select only one)	
Viral pneumonia	3
Bacterial pneumonia	3
Asthma	11
Trauma and burn	3
Aspiration pneumonitis	5
Other acute respiratory diagnoses	1
Nonrespiratory and chronic respiratory diagnoses	0
Central nervous system dysfunction†	−7
Acute associated (nonpulmonary) infection‡	−3
Neuromuscular blockade agents before ECMO	1
Nitric oxide use before ECMO	−1
Bicarbonate infusion before ECMO	−2
Cardiac arrest before ECMO	−2
Pa_{CO_2}, mm Hg	
<75	0
⩾75	−1
Peak inspiratory pressure, cm H_2O	
<42	0
⩾42	−1
Total score	−22 to 15

Hospital Survival by Risk Class		
Total RESP Score	**Risk Class**	**Survival**
⩾6	I	92%
3 to 5	II	76%
−1 to 2	III	57%
−5 to −2	IV	33%
⩽−6	V	18%

Definition of abbreviations: ECMO = extracorporeal membrane oxygenation; RESP = Respiratory ECMO Survival Prediction.
An online calculator is available at www.respscore.com.
*"Immunocompromised" is defined as hematological malignancies, solid tumor, solid organ transplantation, human immunodeficiency virus, and cirrhosis.
†"Central nervous system dysfunction" diagnosis combined neurotrauma, stroke, encephalopathy, cerebral embolism, and seizure and epileptic syndrome.
‡"Acute associated (nonpulmonary) infection" is defined as another bacterial, viral, parasitic, or fungal infection that did not involve the lung.

Factors influencing ECMO outcome

- Age
  - Not a strict cutoff
- Good expected medium-to-long term outcome without acute illness
  - i.e., free of condition with high near-term mortality
- Early application of lung protective ventilation
- Early application of adjunctive strategies
- Early referral for consideration of ECMO

Timing of ECMO referral

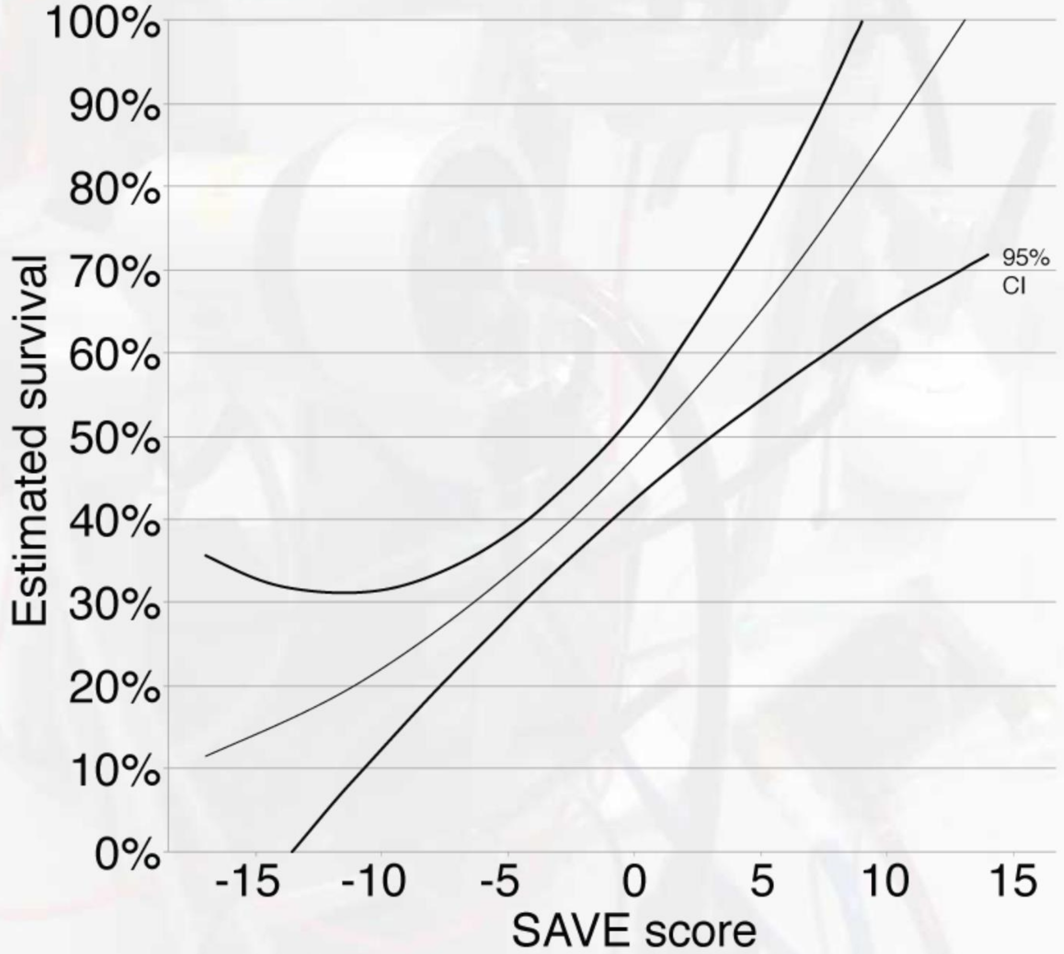
- In an appropriate candidate:
  - PF <50 for >3 hours despite ventilator optimization and use of adjunctive measures OR
  - PF <100 for >6 hours despite attempted optimization OR
  - pH <7.20 with predominantly respiratory component despite attempted optimization
- Early referral is key to improving outcomes

SAVE

Survival **A**fter **V**eno-arterial **E**CMO

The SAVE 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 refractory cardiogenic shock. It should not be considered a substitute for clinical assessment.

For more information see: *Predicting survival after ECMO for refractory cardiogenic shock: the survival after veno-arterial-ECMO (SAVE)-score*



The patient's SAVE Score is

Diagnosis:
- Myocarditis
- Refractory VT/VF
- Post heart or lung transplantation
- Congenital heart disease
- Other diagnoses

Age (years): 18-38 / 39-52 / 53-62 / ≥63

Weight (kg): <65 / 65-89 / ≥90

Cardiac:
- Pulse pressure pre ECMO ≤20 mmHg
- Diastolic BP pre ECMO ≥40 mmHg
- Pre-ECMO cardiac arrest

Respiratory:
- Peak inspiratory pressure ≤20 cmH_2O
- Intubation duration pre ECMO (hrs): ≤10 / 11-29 / ≥30

Renal:
- Acute renal failure
- Chronic renal failure
- HCO_3 pre ECMO ≤15 mmol/L

Other organ failures pre ECMO:
- Central nervous system dysfunction
- Liver failure

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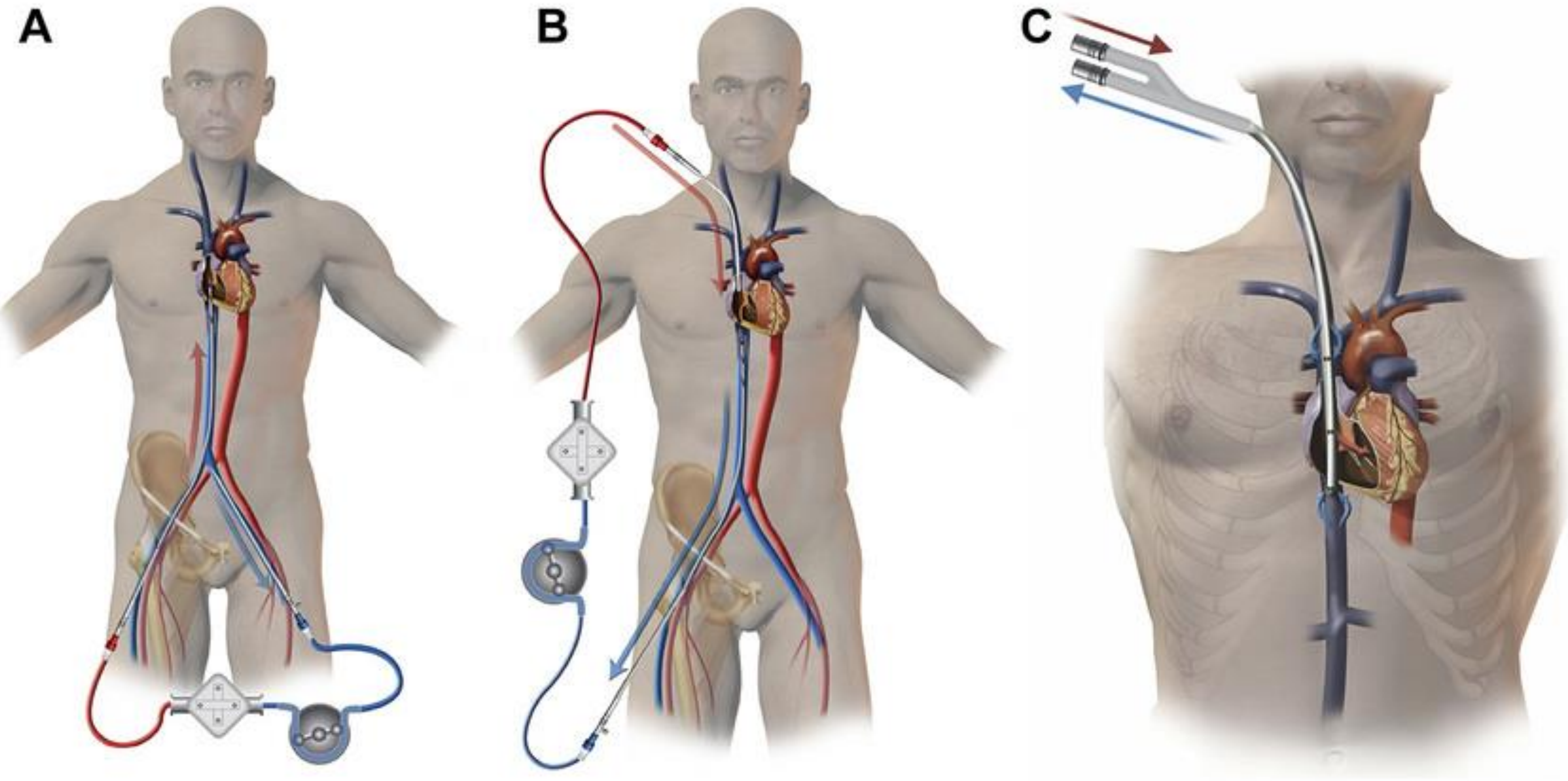
ECLS(ECMO) Circuit

Types

- Veno –arterial (VA)
- Veno- Venous (VV)
- Veno-arterial-venous (VAV)

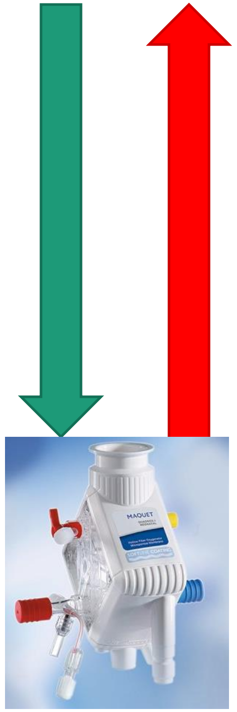

A
B
C

Venoarterial ECMO	Venovenous ECMO
Higher PaO_2 is achieved	Lower PaO_2 is achieved
Lower perfusion rates are needed	Higher perfusion rates are needed
Bypasses pulmonary circulation	Maintains pulmonary blood flow
Decreases pulmonary artery pressure	Increases mixed venous PO_2
Provides cardiac support to assist systemic circulation	Does not provide cardiac support to assist systemic circulation
Requires arterial cannulation	Requires only venous cannulation

Types of ECMO

SVC
IVC

RA RV PA Lungs LA LV AO



Veno-Venous

Types of ECMO

SVC
IVC

RA RV PA Lungs LA LV AO

RA-PA (RVAD)

Types of ECMO

SVC
IVC

RA RV PA Lungs LA LV AO

Veno-Arterial
(Central or Peripheral)

Types of ECMO

SVC
IVC

RA RV PA Lungs LA LV AO

LV or LA – Ao
(LVAD)

Types of ECMO

SVC
IVC

RA RV PA Lungs LA LV AO

RA-PA (RVAD)

LV or LA – Ao (LVAD)

ECMO Circuit

- Pump
- Oxygenator
- Cannulae
- Tubing
- Gas / Heat exchanger

- No Reservoir
- No suckers

Pump

- Types
  - Roller Pumps
  - Centrifugal pumps

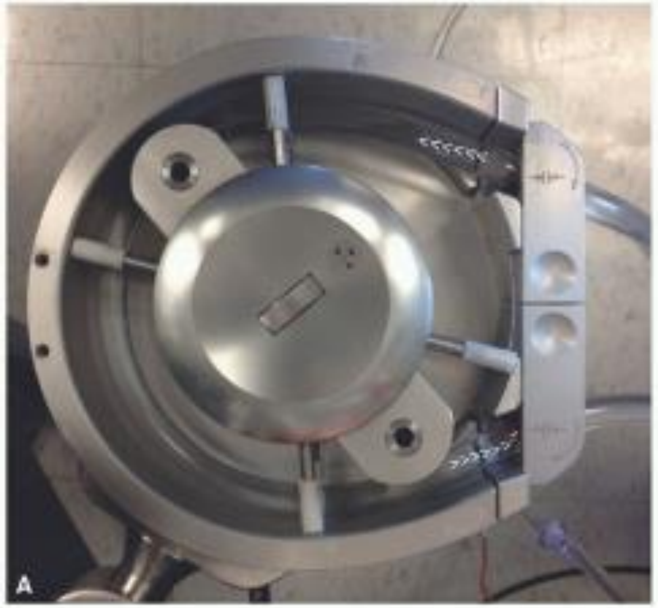


Table 2 Roller versus Centrifugal Pump.

	Roller pump	Centrifugal pump
Description	Occlusive	Non-occlusive
	Independent from afterload	Sensitive to afterload
Advantages	Prime volume is small	Portable
	Cheap	Adjusting positive and negative pressure is safe
	No backflow occurs	Adapts to venous return
	Shallow sine-wave pulse	Massive air-embolism does not occur
Disadvantages	Excessive positive and negative pressure	Priming volume is large
	The risk of spallation	Flow-metre is necessary
	The risk of tubing rupture	Potential passive backward flow
	The risk of massive air-embolism	Expensive
	Necessary occlusion adjustments	
	Vulnerable to careless operation	

Oxygenator

Hollow fiber PMP oxygenator

- extremely efficient at gas exchange
- minimal plasma leakage;
- have relatively low resistance to blood flow
- Easy to prime;
- well suited for use with centrifugal blood pumps
- Integrated heat exchange device

Eg.

- Quadrox-iD (Maquet, Hirrlingen, Germany),
- Hilite LT (Medos, Stolberg, Germany),
- Lilliput 2 (Sorin, Mirandola Modena, Italy)
- Biocube (Nipro, Osaka, Japan.)

Cannulae


MAQUET
MAQUET

Keys for successful femoral cannulation

- Avoid femoral cannulations for PVD, small vessels (U/S), Obese pts
- U/S guide, avoid back wall puncture, avoid SFA puncture
- Stiff wire
- Large skin cut, Good dilators, hold the wire tight when you push a dilator
- TEE/fluoroscopy guiding, xray to avoid RV perforation or aortic dissection
- Secure the distal superficial femoral artery perfusion before femoral cannulation if possible/needed
- Think about which side you cannulate, artery and vein
  - Sewing a graft on, most likely hyperperfuse distally. Place the venous cannula on the contralateral side
  - If removing arterial cannula later to move on to central, cannulate artery only for the later repair sx.
  - Venous cannulation may be better on the right, but no clinical difference.
- Arterial first, then venous
  - Leave obturators in
  - Confirm No clot in the cannulas before initiate ECMO

Central cannulation

- Over 20 Fr. Aortic cannulation
- 32-36 Fr Venous cannula to the RA
- Tunnel through the upper abdomen
- Close the chest with cannulas in

- Minimally invasive aortic cannulations
  anterior thoracotomy for arterial cannulation
  Peripheral venous cannulation

Peripheral, Central or Hybrid

	Peripheral (groin)	Central (aorta)	Hybrid (axillary)
Location	Bedside	OR	OR
Target	Small vessel Distal mal-perfusion Possible graft utilization and distal hyperemia	Aortic cannulation	Small-Medium vessel Less diseased Graft utilization and distal hyperemia
Flow	Reverse flow in the descending aortic arch	Antegrade brain perfusion	Antegrade brain perfusion
Approach	No sternotomy	Sternotomy Mini-thoracotomy	No sternotomy
Bleeding	Graft bleeding	Bleeding related to sternotomy	Graft bleeding

Peripheral, Central or Hybrid

- No evidence
- It appears to be reasonable if you can central/Hybrid cannulation if
  - Patient condition
  - Logistics, OR available
- Hybrid and ambulatory ECMO
- Avoid limb ischemia
  - Small size cannula
  - Distal limb perfusion

The effect of extremity vascular complications on the outcomes of cardiac support device recipients

J. Westley Ohman, MD,[a] Chandu Vemuri, MD,[a] Sunil Prasad, MD,[b] Scott C. Silvestry, MD,[b]
Jeffrey Jim, MD, MPHS,[a] and Patrick J. Geraghty, MD,[a] *St. Louis, Mo*

JOURNAL OF VASCULAR SURGERY
Volume 59, Number 6

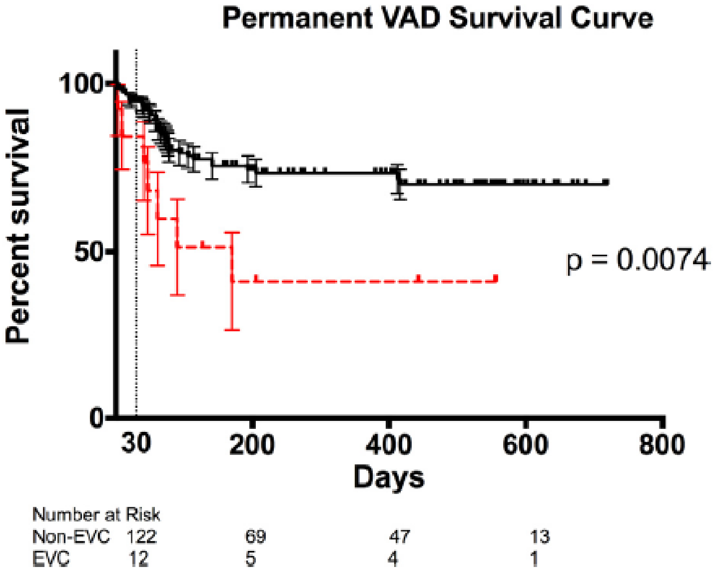


Table VII. Mortality outcomes for all three subgroups

	Non-EVC, No. (%)	*EVC, No. (%)*	P *value*
30-day mortality			
Temporary	10 (35.7)	8 (80.0)	.0265
Permanent	6 (4.5)	2 (15.4)	.1510
ECMO	11 (68.8)	4 (50.0)	.4120
30-day withdrawal of care			
Temporary	4 (14.3)	8 (80.0)	.0004
Permanent	8 (6.0)	3 (23.1)	.0602
ECMO	11 (68.8)	4 (50.0)	.4120

ECMO, Extracorporal membraneous oxygenation; *EVC*, extremity vascular complication.
All mortality *P* values were computed using Fisher exact test.

- Limb ischemia = higher mortality?
- Distal perfusion cannula reduces limb ischemia

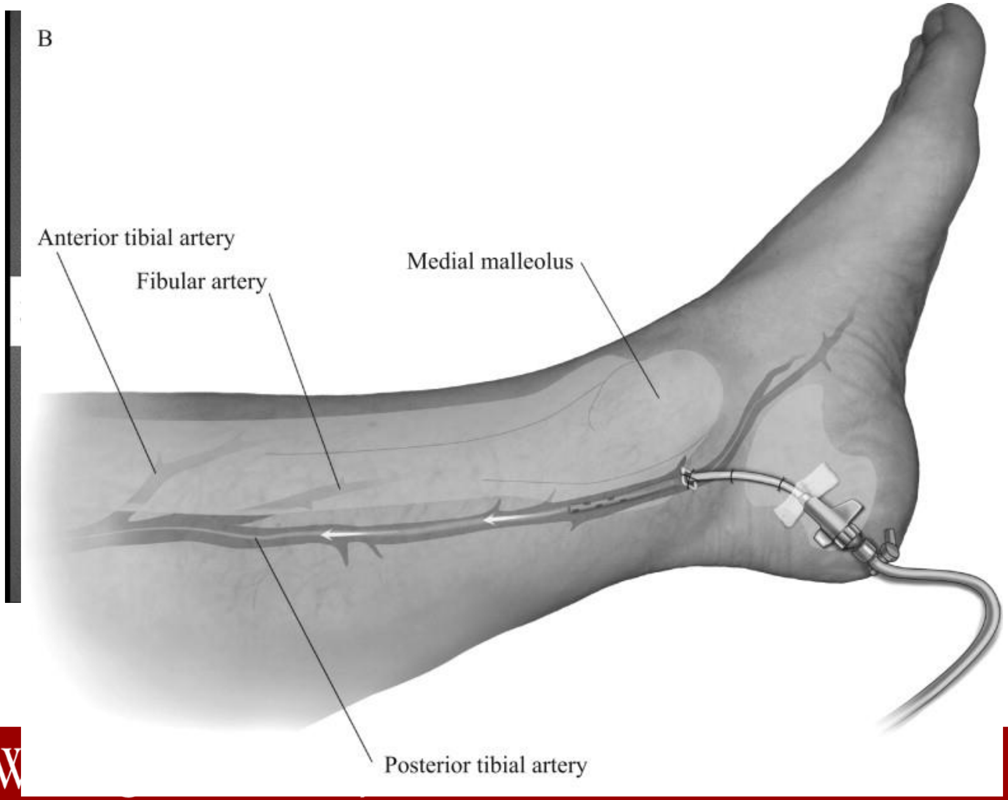
Perfusion

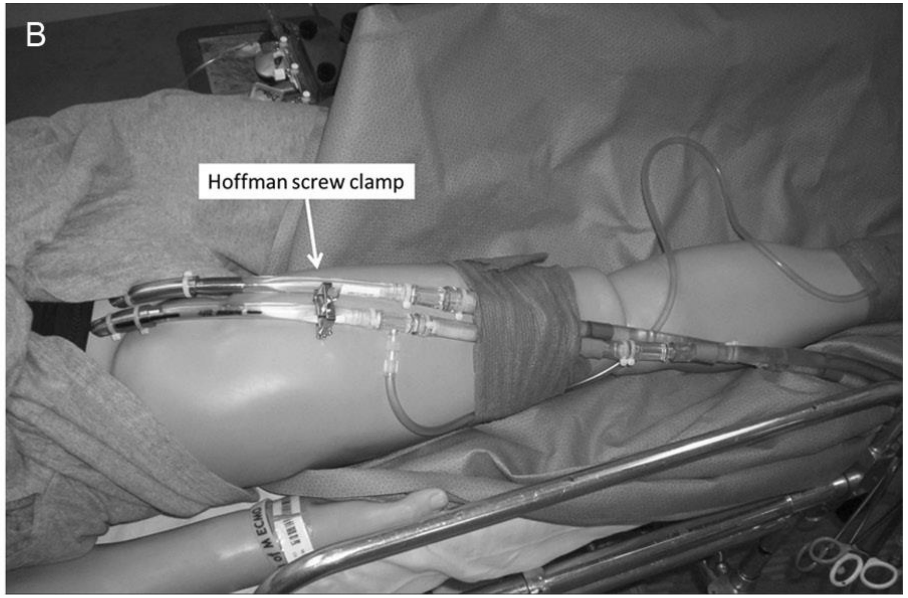
A simple technique to prevent limb ischemia during veno-arterial ECMO using the femoral artery: the posterior tibial approach

Perfusion
27(2) 141–145

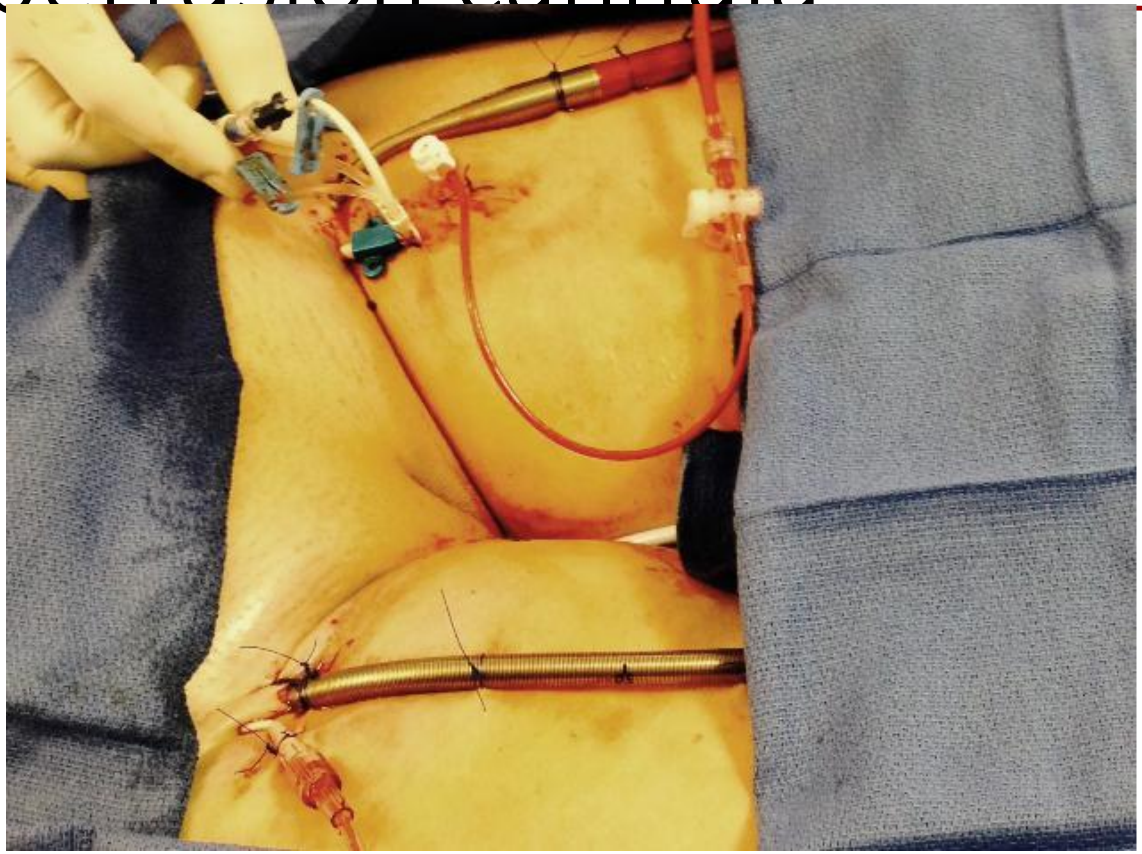
DOI: 10.1177/0267659111430760
prf.sagepub.com
SAGE

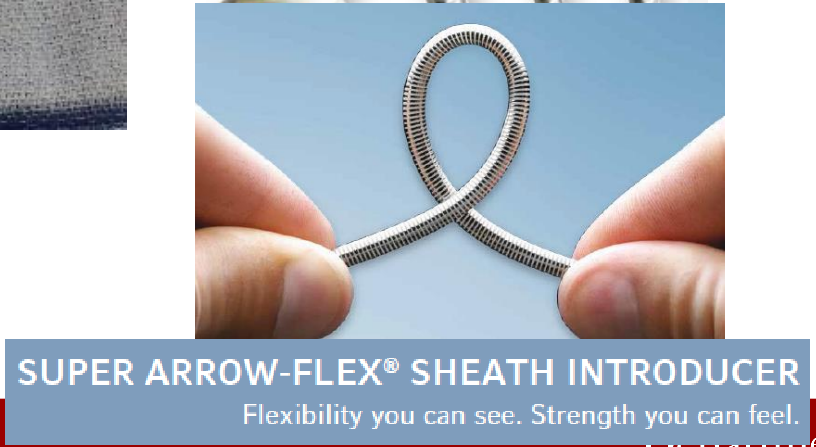
DJ Spurlock, JM Toomasian, MA Romano, E Cooley, RH Bartlett and JW Haft





SFA perfusion cannula

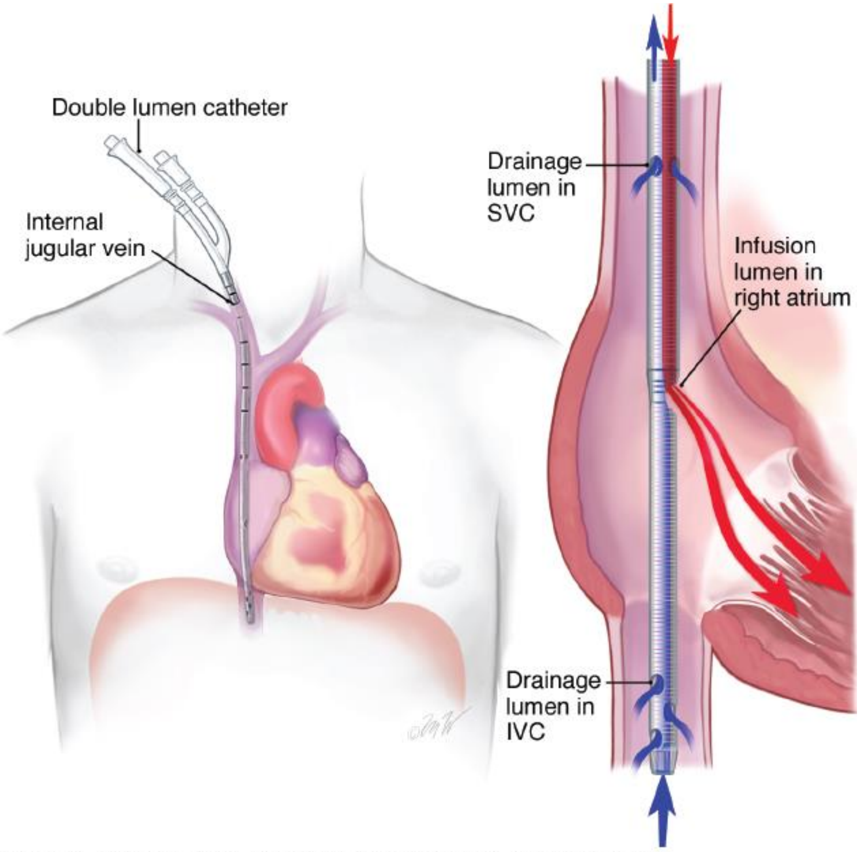




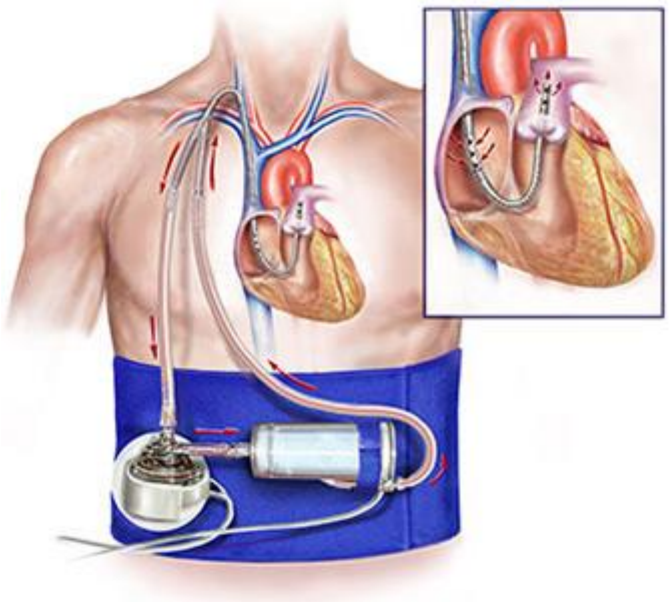
Open repair for decannulation

Distal perfusion cannula

Dual lumen cannula



Source: D. J. Sugarbaker, R. Bueno, Y. L. Colson, M. T. Jaklitsch, M. J. Krasna, S. J. Mentzer, M. Williams, A. Adams: *Adult Chest Surgery*, 2nd Edition: www.accesssurgery.com



Tubing

- Medical grade polyvinyl chloride tubing is universally used
- flexible, compatible with blood,
- inert, nontoxic, smooth, transparent, and resistant to kinking and collapse
- Heat sterilised.
- Bioactive coating of artificial surfaces with heparin or albumin

Mixer/blender

LV VENT with VA ECMO Options

- No vent
- IABP
- Percutaneous VAD (Impella, PHP)
- Atrial septostomy (Tandem Heart)
- Surgical LV vent
  - LV apex
  - LA to LV
  - PA vent

IABP with ECMO

- Not clear survival benefit
  - Lin 2016, Cheng 2015
- Likely hemodynamical advantage
  - Ma 2014, Madershahian 2011

- IABP is in place already
  - No need to remove unless LVEDP increase
  - Heparin/coagulopathy
  - Limb ischemia/bleeding

Impella with ECMO

- Likely unload the LV with ECMO
  - Cheng 2013, Guirgis 2015, *Tepper 2016*
- Can be initiated in the cathlab
- Hemolysis
  - Cardozo 2015, Sibbald 2012
- Valvular issues
  - Mitral valve leaflet injury   Eftekhari 2016
  - Aortic valve injury
- Distal limb ischemia

ECMO + Impella

Title: Left Ventricular Unloading by Impella Device versus Surgical Vent during Extracorporeal Life Support

Running Head: Impella vs. Surgical Vent During ECLS

Authors: Sarah Tepper, Muhammad Faraz Masood, Moises Baltazar Garcia, Molly Pisani, Gregory Ewald, John Lasala, Richard Bach, Jasvindar Singh, Keki Balsara, Akinobu Itoh

Table 4. In-hospital Outcomes and Complications

	ECLS + Impella (n=23)	ECLS + Surgical Vent (n=22)	p value
Survival			
48 hours	20 (87)	21 (95)	0.61
28 days	11 (48)	7 (32)	0.27
ICU discharge	8 (35)	5 (23)	0.37
Length of combined support, days	5 [2-7]	7 [4-12]	0.11
ECLS decannulation	13 (57)	10 (45)	0.46
Bridged to VAD	7 (30)	4 (18)	0.34
Pulmonary edema reduced or unchanged after 48 hours	18 (90)	16 (76)	0.67
Cause of death			
Bleeding	1 (4)	1 (5)	0.99
Cardiac death	4 (17)	8 (36)	0.19
Infection	1 (4)	2 (9)	0.61
Multiple system organ failure	8 (35)	5 (23)	0.37
Stroke	1 (4)	1 (5)	0.99
Vascular complications			
Bleeding	9 (39)	10 (45)	0.67
Hemolysis	5 (22)	1 (5)	0.19
Hypoperfusion/limb ischemia	3 (13)	4 (18)	0.70

ECLS – extracorporeal life support; ICU – intensive care unit; VAD – ventricular assist device

Table 3. Hemodynamic and laboratory data before and after 48 hours of support

	ECLS + Impella (n=20)			ECLS + Surgical Vent (n=21)		
	Pre-combined support	48 hours	p value	Pre-combined support	48 hours	p values
CVP (mmHg)	12.4 ± 5.9	9.7 ± 3.5	0.02	15.1 ± 7.2	13.2 ± 5.8	0.12
AST (U/L)	613 [176–2069]	292 [123–477]	0.004	169 [72–1104]	238 [145–749]	0.30
ALT (U/L)	560 [87–1590]	280 [50–571]	0.002	128 [42–696]	139 [44–658]	0.42
Creatinine (mg/dL)	2.0 ± 0.8	1.9 ± 0.8	0.82	1.9 ± 0.3	1.7 ± 0.2	0.42
	ECLS + Impella (n=10)			ECLS + Surgical Vent (n=14)		
PADP (mmHg)	23.3 ± 8.4	15.6 ± 4.2	0.02	20.1 ± 5.9	15.6 ± 5.4	0.01

ALT – alanine aminotransferase; AST – aspartate aminotransferase; CVP – central venous pressure; ECLS – extracorporeal life support; PADP – pulmonary artery diastolic pressure

Therapies IV, Poster session AHA 2016

Anticoagulation

- Initial small dose of heparin (2-5k), ACT 200 for cannulations
- Leave obturators in until the last minute, cannulate arterial first
- Run ECMO without heparin/bivalirudin (HIT) with clinical bleeding
- 24 to 48 hours after ECMO initiation start 500-750u/hr of Heparin, then PTT 60-90sec
- ACT
- Anti Xa
- POC
    - TEG
    - ROTEM

Weaning- No magic!

- Bridge to RECOVERY or bridge to MCS, potentially heart transplant.

- Serial echocardiogram
  - EF>30-40% with ECMO flow down to 1-2 L/m
  - No valvular issues or ongoing ischemia

- Clinical observation
  - Bedside weaning test, down to 1-2 L/m
  - Good Pulsatility with inotropics/vasopressors
  - Neurologically intact, clear head CT scan
  - Respiratory tolerable condition, bronchoscopy on ECMO, otherwise VV ECMO

- Add other circulatory support
  - IABP (Femoral or axillary)
  - Impella (Femoral or axillary)
  - LVAD/BIVAD for HTx or DT

Decannulation

- No heparin and decannulate with solid confidence of heart recovery.
- ACT >200, clamp cannulas, disconnect tubings and recirculate the ECMO circuit
- Volume, inotropic and mechanical support with TEE
  - Auto transfusion via ECMO circuit
  - IABP or impella

ECMO management

Table 3 Initial Settings and Goals for ECMO.

Circuit flow	50–80 mL/kg/min
Sweep gas flow	50–80 mL/kg/min
Fractional inspired oxygen	100%
Inlet pressure (centrifugal pump)	>100 mmHg
Oxygen saturation (return cannula)	100%
Oxygen saturation (drainage cannula)	>65%
Arterial oxygen saturation	VA: >95% VV: 85–92%
Mixed venous oxygen saturation	>65%
Arterial carbon dioxide tension	35–45 mmHg
pH	7.35–7.45
Mean arterial pressure	65–95 mmHg
Haematocrit	30–40%
Platelet count	>100,000 mm^3

ECMO management

- Mechanical ventilation is continued during ECMO support
- Lung protective ventilation strategies
- PCO2 control through ECMO
- Cardiac resting by reduction of inotropes and pressors
- LV venting
- Maintenance of pulsatility- inotropes and IABP

Causes	References	Expected outcomes	Comments
AMI	[11••,12–17]	30–60% survival	Likely to vary according to
			• Time to revascularization
			• Proximal versus distal/diffuse coronary artery disease
			• Underlying chronic heart disease
			• Occurrence of cardiac arrest prior to ECMO
			• Occurrence of structural complications (VSD/MR/ myocardial rupture)
Myocarditis	[14,18,19]	>65% survival	Diagnostic group associated with the best survival
Cardiomyopathy	[11••,14,20]	20–60% survival	Acute decompensated heart failure with severe chronic cardiomyopathy. VA ECMO is a bridge to long-term durable VAD and transplantation
Pulmonary embolism	[21]	40–70% survival	Many case reports of successful VA ECMO. Often reversible but outcome depends on occurrence of cardiac arrest prior to ECMO
Septic shock/myocardial depression	[22••,23•]	10–70% survival	Highly variable outcomes reported. Heterogeneous population. Confounding effects of excessive catecholamine toxicity
Post cardiotomy	[14,24]	20–40% survival	Difficult group. Often heterogeneous with AMI cases included. High rates of bleeding expected
Cardiac failure following heart and lung transplantation	[14,25,26]	40–75% survival	Acute right ventricular failure most commonly seen with preoperative pulmonary artery hypertension. Left ventricular failure also occurs

AMI, acute myocardial infarction; ECMO, extra-corporeal membrane oxygenation; MR, mitral regurgitation; VA ECMO, veno-arterial extracorporeal membrane oxygenation; VAD, ventricular assist devices; VSD, ventricular septal defect.

Complications

- Bleeding
  - Cannulation site
  - Chest tube insertion site
  - ICH
  - GI bleed
  - Retroperitoneal, nasopharyngeal, airway..
- Thrombosis
  - DVT
  - Circuit thrombosis (hypercoagulable status)
  - Oxygenator thrombosis
  - Stroke with debris in the arterial system
- Air emboli
  - iatrogenic R->L shunt, central line air bubbles -> Anoxic brain injury
  - air suction to malpositioned venous cannula -> circuit exchange
- Gas exchange, circuit issues
  - Hypoxemia, cerebral ischemia
  - Hypocapnea, cerebrovascular spasm
  - Tube rupture or disconnection-> lethal exsanguination

Complications	Definition/causes	Treatment
Differential hypoxia	Differential hypoxia occurs when hypoxaemic blood from the pulmonary circulation (large intrapulmonary shunt present) is ejected from the left heart while fully oxygenated blood enters the arterial circulation from peripheral VA ECMO (not central ECMO)	Wean off inotropic agent;
		treat the lung shunt (PEEP, FiO2, bronchoscopy etc.);
		increase ECMO circuit flow (reduce native cardiac output);
		consider changing mode of ECMO from V-A ECMO to V-V ECMO or V-AV ECMO
Leg ischaemia	Caused by occlusive and compressive effects of femoral artery return cannula	Distal perfusion cannula should be inserted in all patients with femoral artery cannulation
		Surgical repair following decannulation
Excessive lung ventilation/ titration of FGF to the ECMO circuit	Pulmonary ventilation and CO_2 clearance via the lungs will vary depending on the extent of native circulation during ECMO	In the setting of minimal native cardiac output (minimal pulsatility/heart beating), lung ventilation should be reduced to prevent profound local alkalosis

LV distension and pulmonary haemorrhage	LV distension can occur in the setting of AI greater than native cardiac stroke volume and/or disproportionate LV dysfunction in relation to RV function [that is, native RV output (into the pulmonary circulation) is greater than native LV function (unable to empty blood from the pulmonary circulation into the systemic circulation)]	Pre-ECMO echocardiography: ECMO is contraindicated in the setting of significant AI with negligible native cardiac function (NB AI may be underestimated in the setting of severe hypotension/cardiogenic shock)
		Optimize LV unloading (reduce MAP to facilitate LV ejection; increase inotropes; reduce ECMO flow where tolerated – particularly useful where LV distension has occurred in the setting of AI; NB increasing inotropes and reducing ECMO flows may increase native RV output and potentially worsen the relative RV to LV native output)
		IABP has been recommended to optimize LV afterload – however, this comes at the cost of a reduction in cerebral and coronary blood flow in peripheral VA ECMO and an increased risk of lower limb thrombosis in all forms of ECMO; contraindicated in the setting of AI.
		Increase PEEP to reduce native RV output and reduce LV afterload.
		Consider LV/LA/PA vent
		Consider second venous access cannula and conversion to high flow ECMO to minimize native RV output (likely to reduce LV output – not appropriate if LV distension is due to AI; may increase risk of cardiac thrombosis)

Cardiac/pulmonary thrombosis	In a nonpulsatile or minimally pulsatile heart stasis of the blood promotes thrombosis	Early and partial support prior to cessation of all native cardiac function where possible
		Inotropes to facilitate pulsatility/LV ejection
		Optimize LV unloading (promote pulsatility): lower MAP target and ECMO flow as tolerated
		Early anticoagulation in the absence of contraindication (NB this will reduce the likelihood of thrombosis in a low flow state but is unlikely to prevent thrombosis in the absence of flow)

Ambulatory ECMO

- Increasing volumes of lung transplants and increasing number of patients added
- Mean waitlist mortality of 15.7%
- Mean waitlist time of 3.6 months
- Early outcomes of ECMO in waitlisted patients were poor
- However , ECMO as a bridge to lung tranplantation is now well established

Issues with conventional ECMO

Rationale

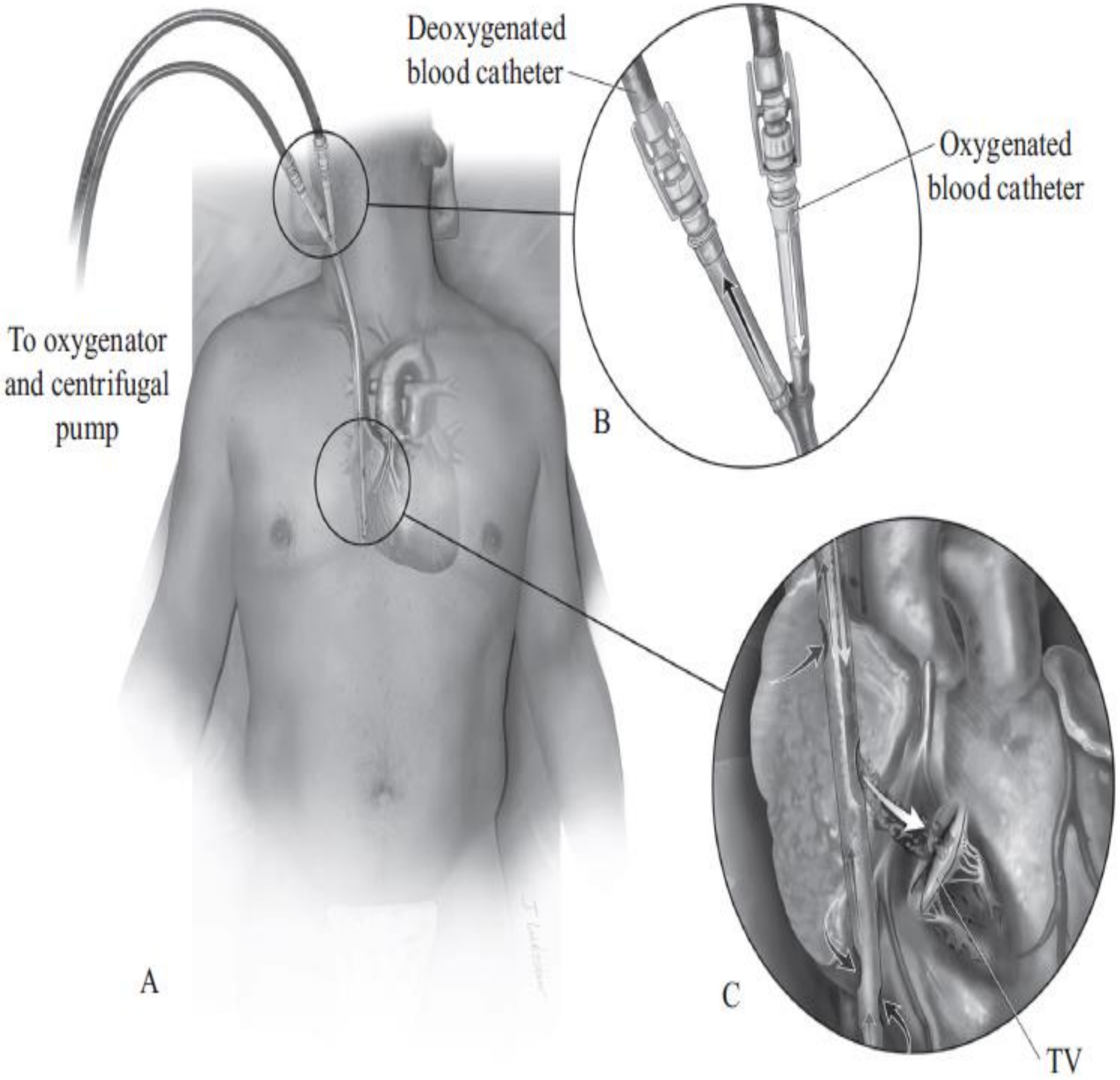
(1) Upright patients who are ambulatory and socially interactive provide the most effective vehicle for clinical recovery or subsequent bridge to transplant.

(2) No lung disease or pulmonary injury benefits from paralysis, sedation, and intubation with non physiological positive pressure ventilation.

- ventilator-associated pneumonias
- Barotrauma as a consequence of positive pressure ventilation
- Requirements of sedation and paralytics to facilitate permissive hypercapnea as a strategy to limit barotrauma
- profound deconditioning of both respiratory and skeletal muscle because of "ventilated, bed-bound" care.

Techniques

- Multiple cannulation strategies are used to facilitate early extubation and ambulation
- Early deployment
- Use of Oxy- RVADs


Deoxygenated
blood catheter
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and centrifugal
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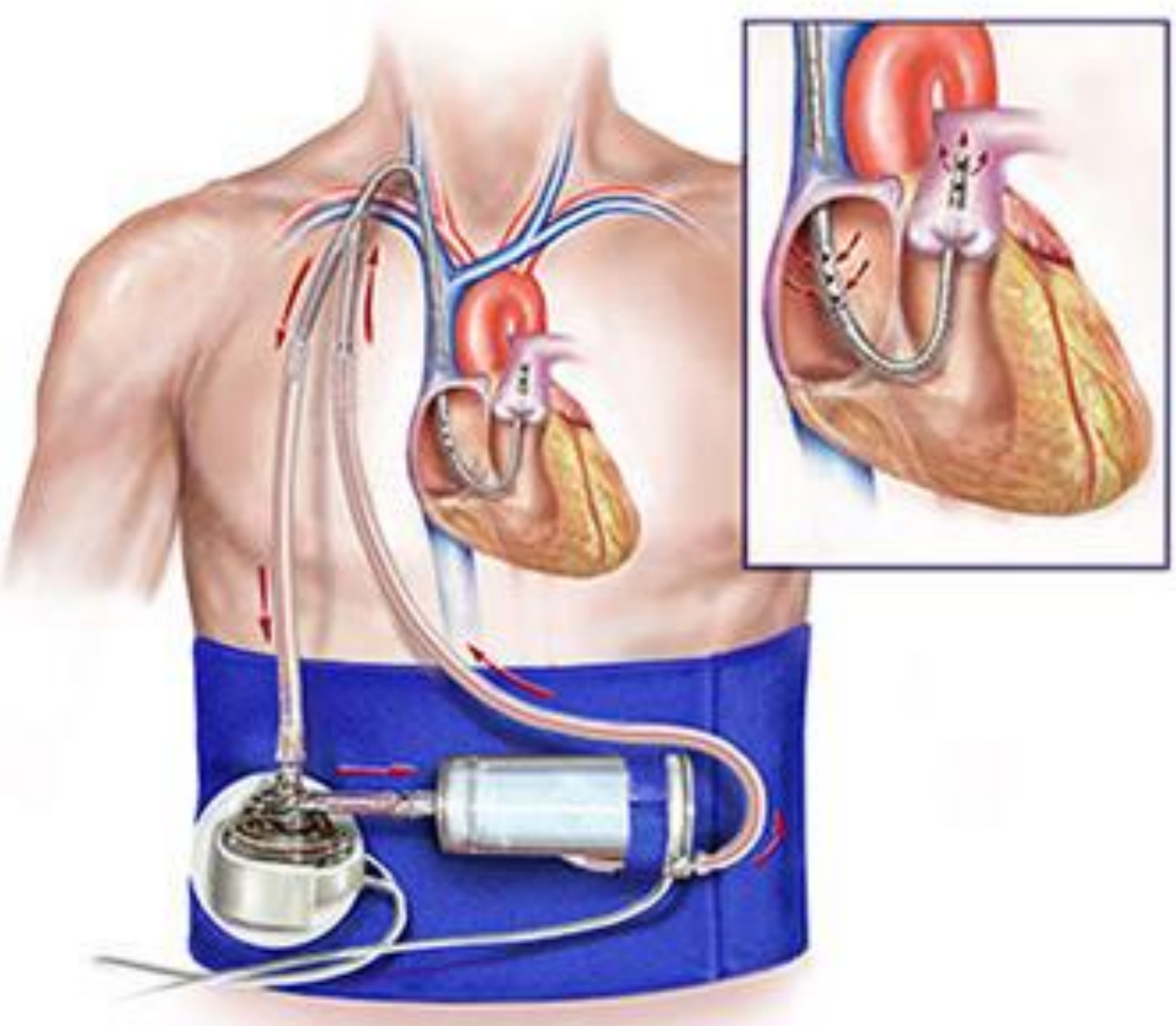
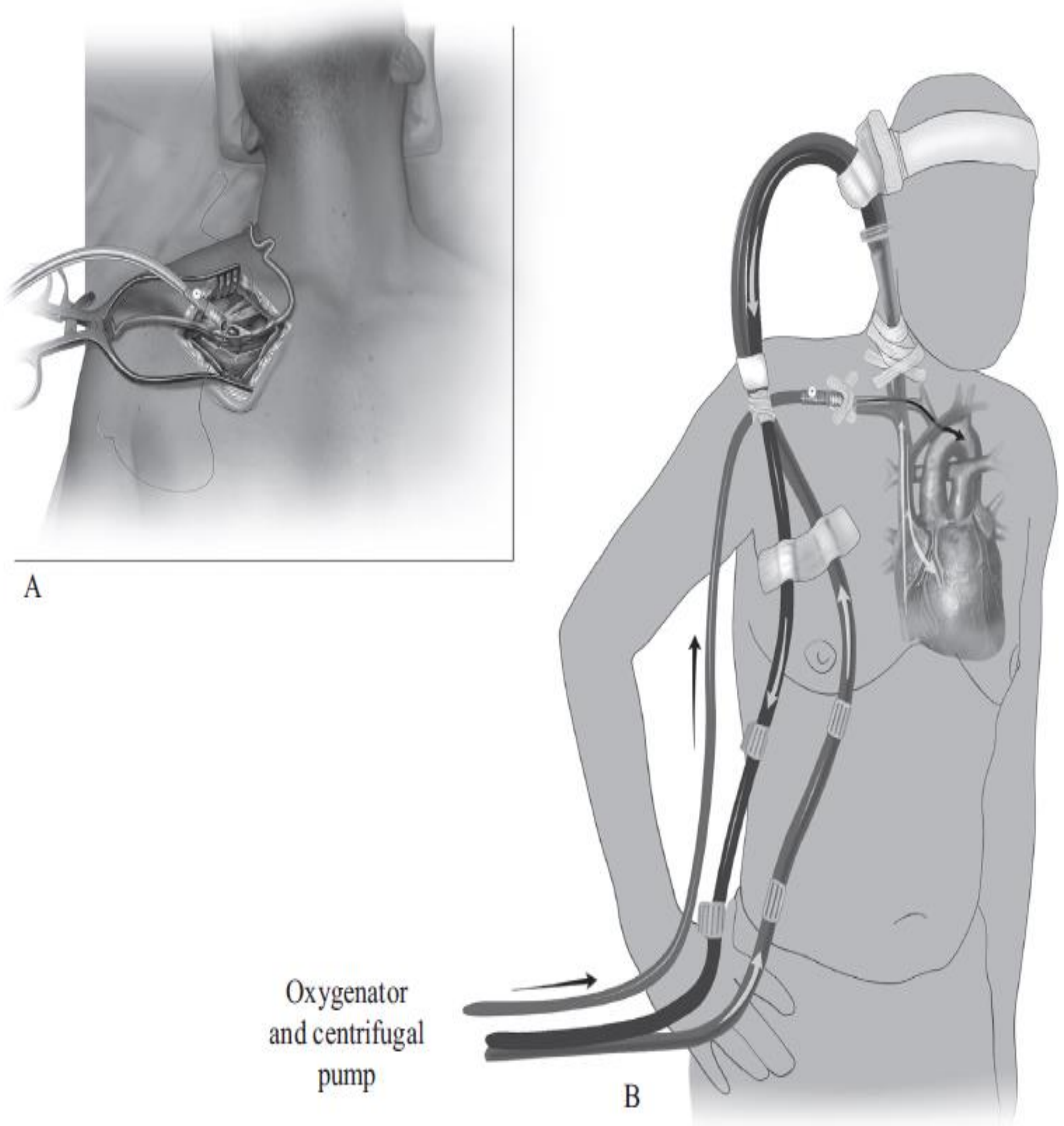
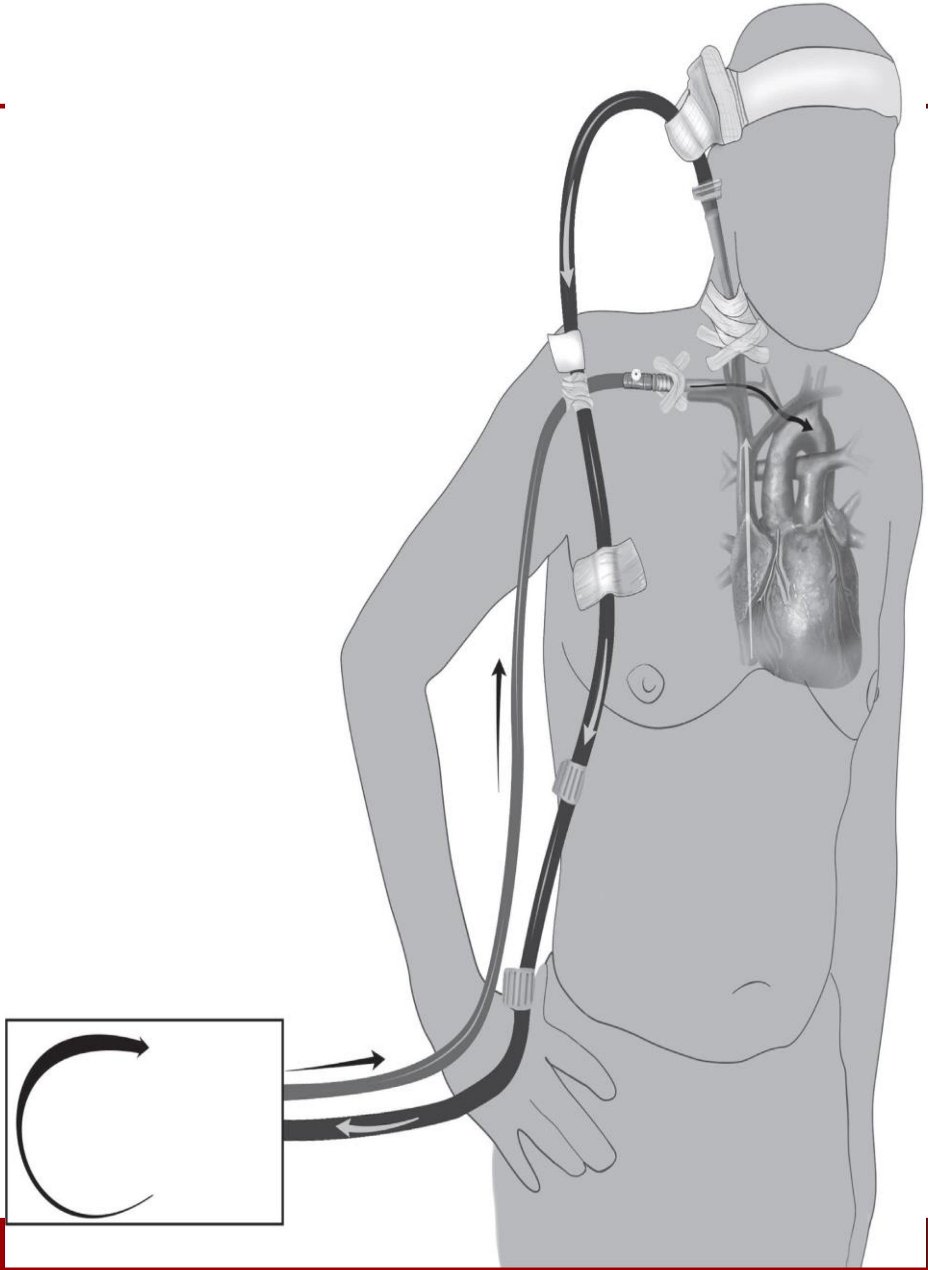
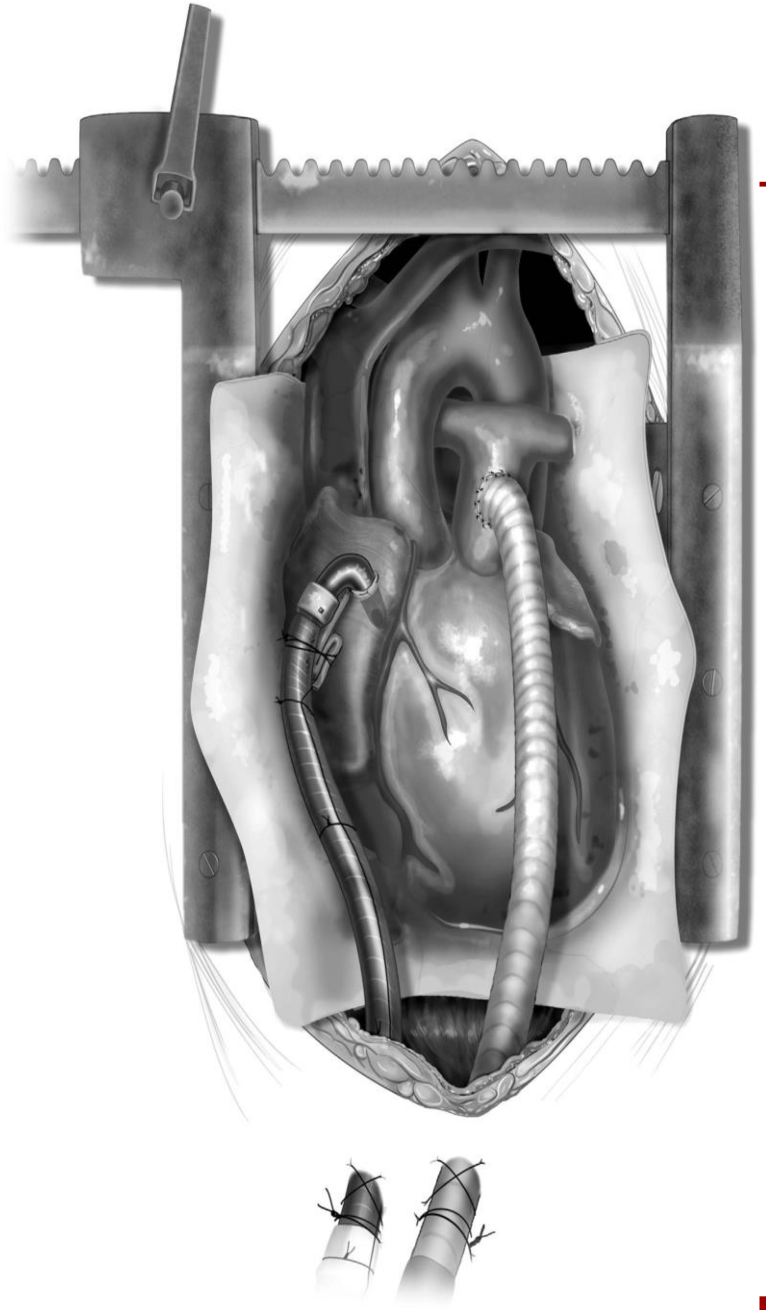
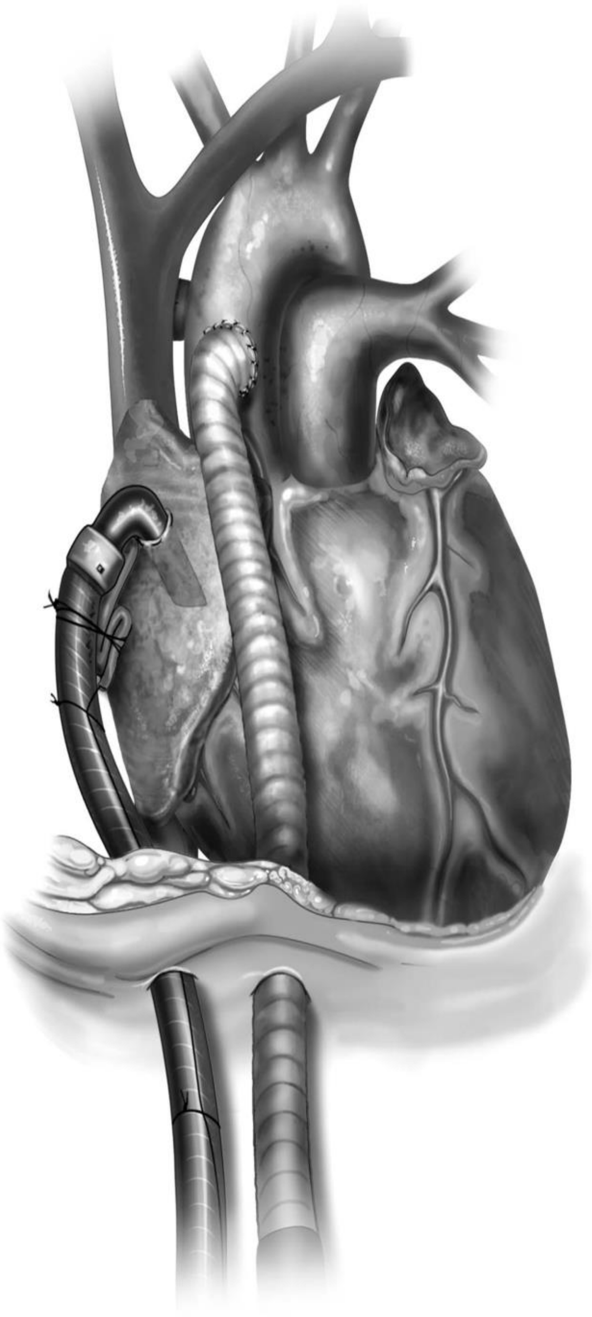
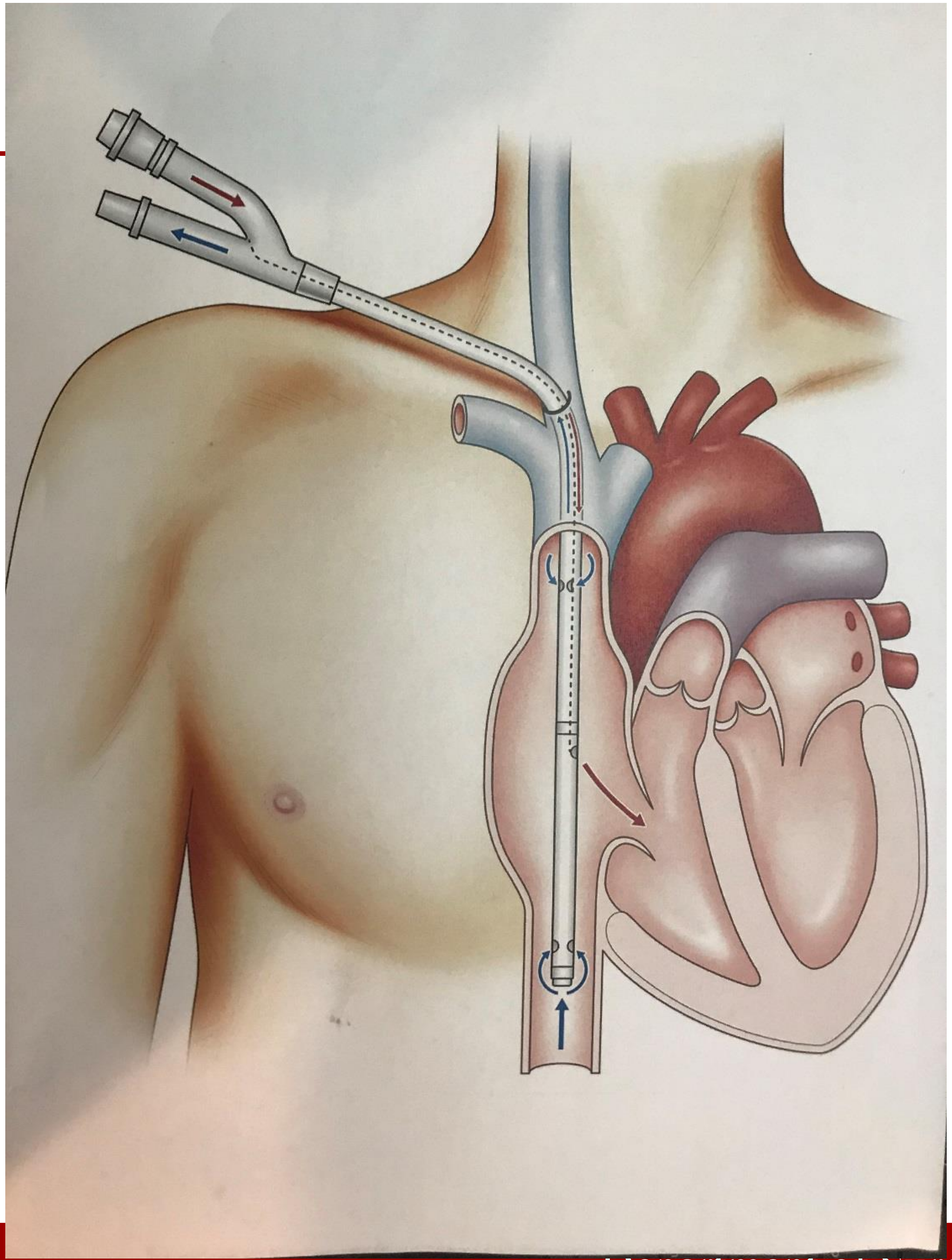


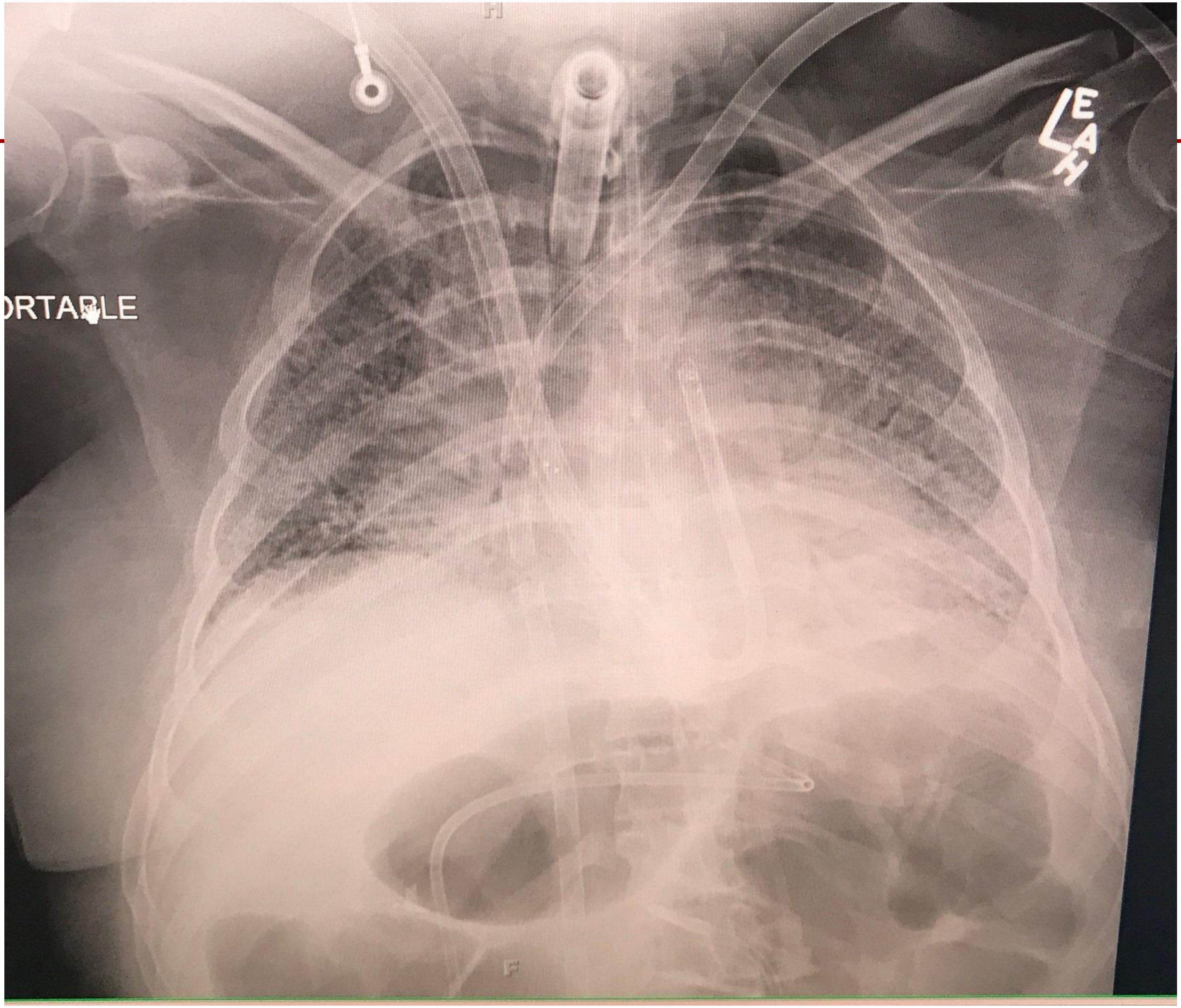

A
Oxygenator
and centrifugal
pump
B







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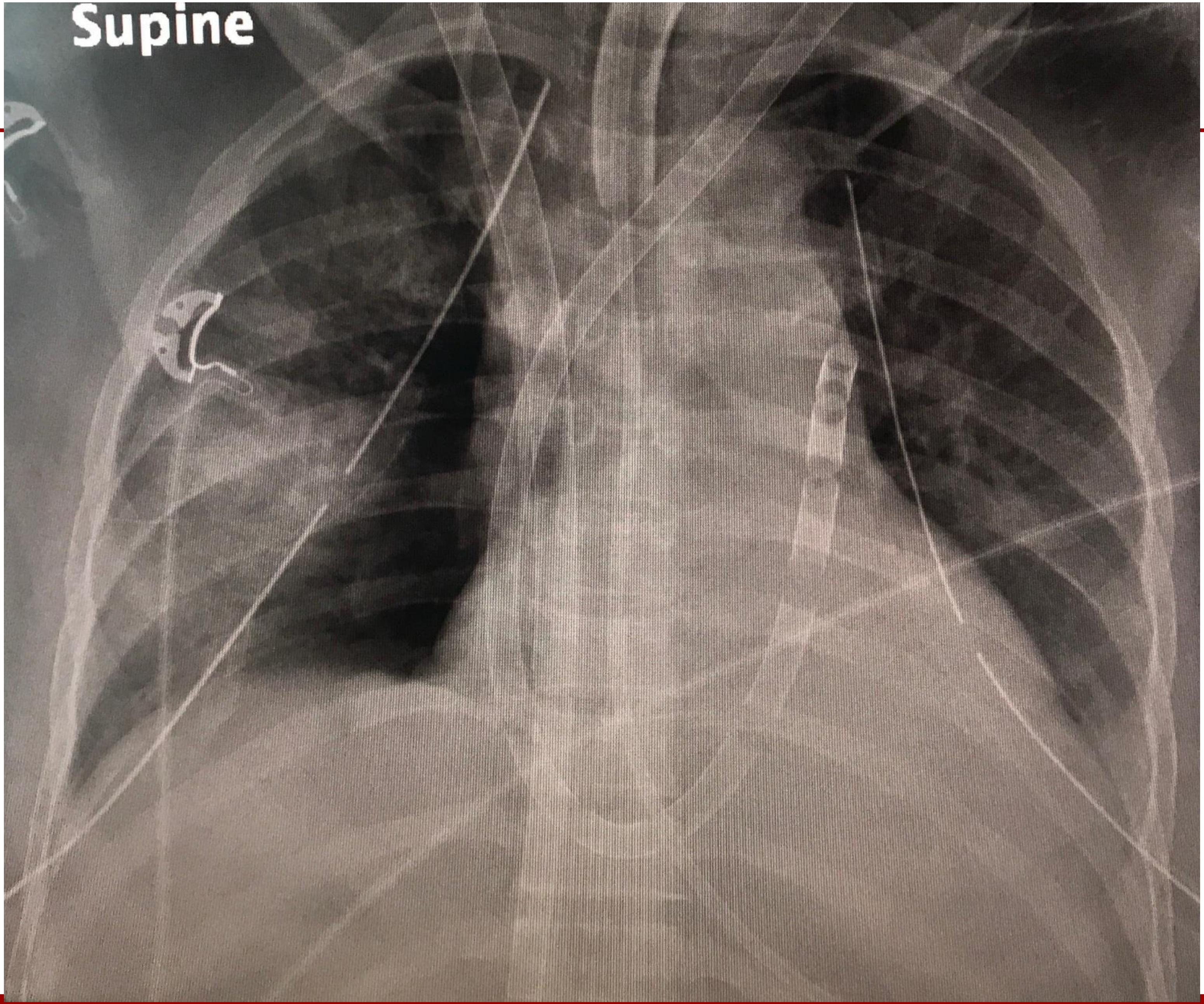

Supine

Our Outcomes

	2013	2014	2015 -Aug
N	86	86	64
Male %	63	64	66
Survival %	46.5	43	40
ICU stay (d)	22±29	20±37	20±37
Total Hospital stay(d)	42±56	33±46	30±32
ECMO to LVAD(n)	17	12	13
Transfer on ECMO(n)	4	8	5

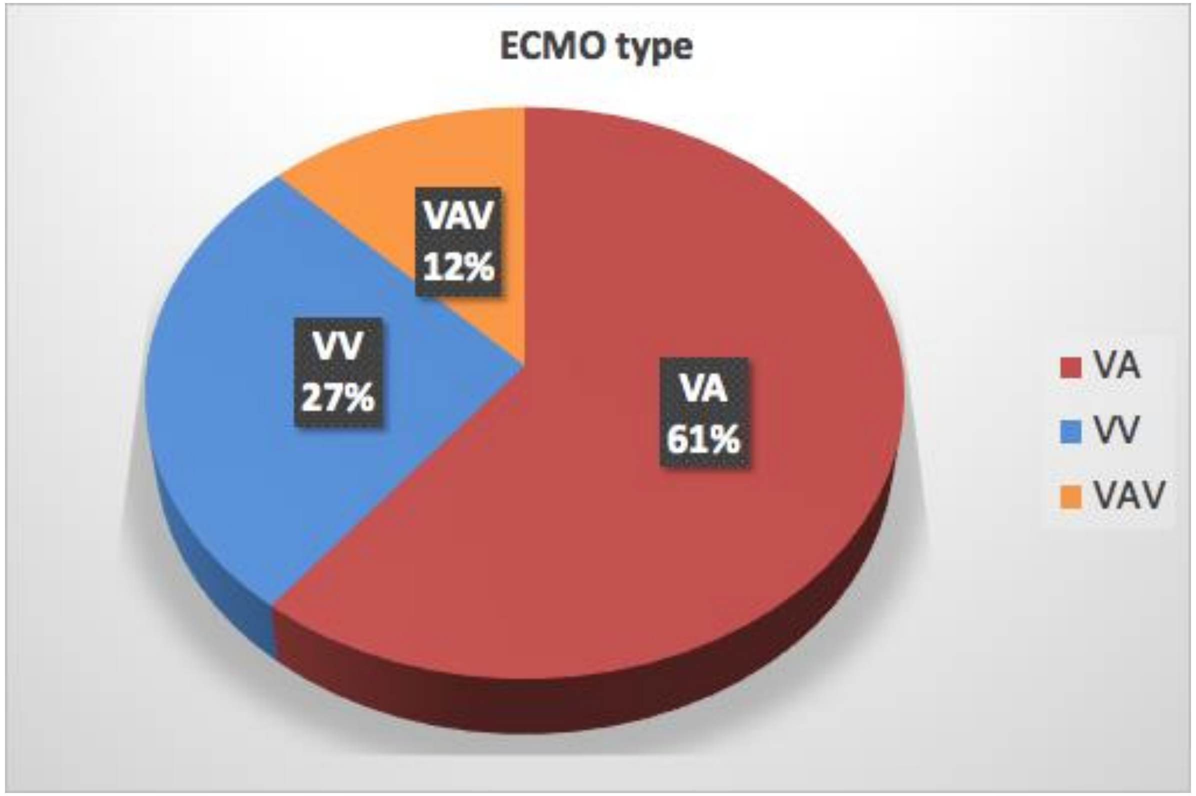
ECMO patients in 2017-18

VIS 01/01/2017~1/20/2018 From RESCUE

Object: ALL ECMO patient

TABLE 1. Demographics and Baseline Characteristics (n = 122)

age	52.2±15.0
Male	70 (57.0%)
BSA	2.03±0.32
Height	172.6±10.8
Weight	91.8±28.6
Alive	54 (44.3%)
Sepsis	6 (4.9%)
Cardiogenic shock	86(70.5%)
Respiratory shock	39(32.0%)
ECMO type	
VA	74(60.7%)
VV	33(27.0%)
VAV	15(12.3%)



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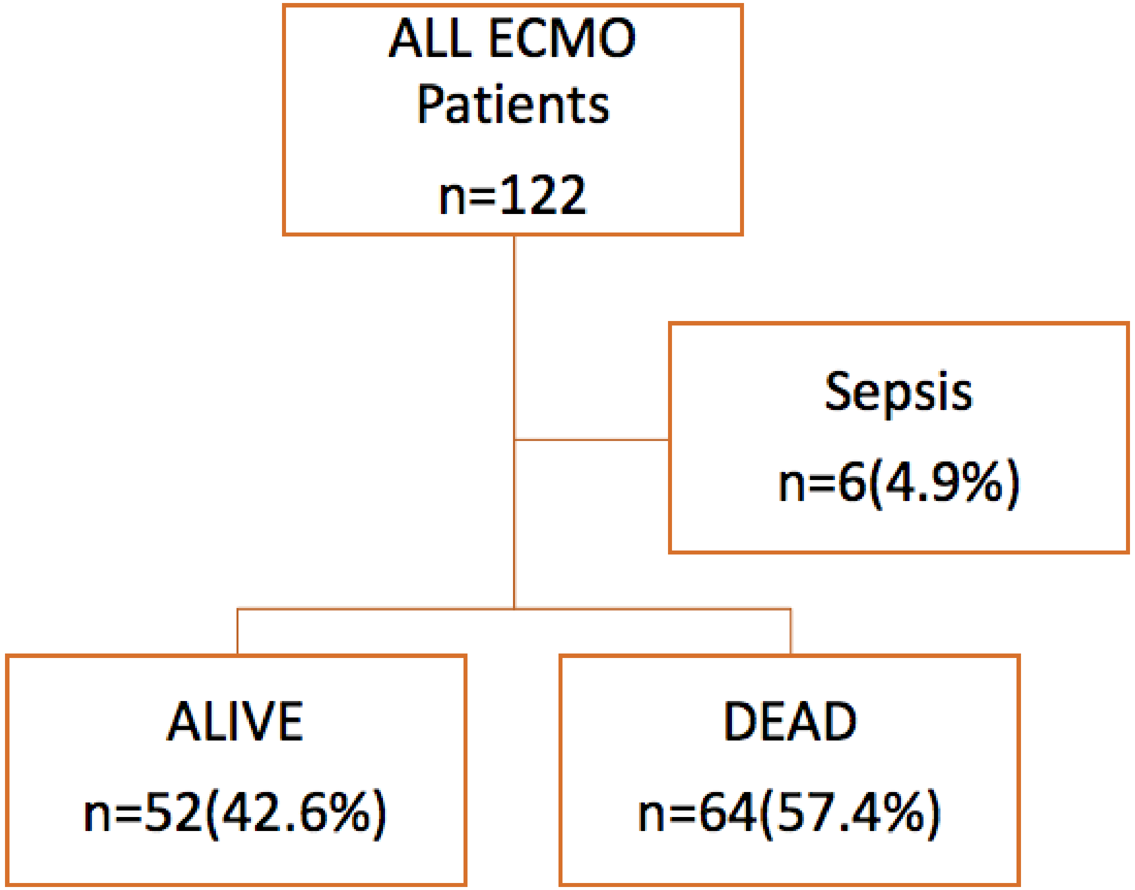

Thank You

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