ECMO: An overview and update for the practicing surgeon

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DISCLOSURE

- There are no actual or potential conflicts of interest in regards to this presentation.

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Learning Objectives

At the conclusion of this lecture participants will be able to:

- Identify patients who are potential candidates for ECMO
- Understand the difference between VA and VV ECMO
- Understand how the physiology behind different ECMO approaches
- Evaluate key trials that influence how ECMO practice patterns are changing

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Take home points

- ECMO is a powerful tool, but there must be a **destination**
- Indications and contra-indications are relative
- Call early!!!

History of ECMO

1930s -1954	Dr Gibbon's contribution to Heart and Lung Machine
1950s	Dr DeWall's Membrane oxygenator
1971	First reportable successful case (NEJM)
1972	First successful pediatric cardiac case
1975	Esperanza-Dr Bartlett's case
1975-89	RCT Zapol et al with 90 % mortality (Neg NIH trial)
1990	Neonates and Pediatric ECLS Centers
2000	Adult ECLS Centers
2009	CESAR trial with survival benefit at centers of excellence

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General Overview ECMO

- Extracorporeal membrane oxygenation (ECMO) is a technique that involves oxygenation of blood outside the body, and provides support to patients with severe cardiac and/or respiratory failure.

- The two major ECMO modalities are veno-arterial and veno-venous

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Before a patient is placed on ECMO

- ECMO has to have a destination
  - Bridge to transplant/surgery
  - Bridge to recovery
  - Bridge to decision

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Patient Selection

<u>Indications for use/Patient selection criteria:</u>

Acute, **reversible** cardiac and/or pulmonary failure when the risk of dying from the condition is greater than the potential risks of ECMO

- Neonates
- Pediatrics
- Adults

Each center develops institutional guidelines for ECMO use including indications and contraindications (relative and absolute)

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VA ECMO Patient Selection

Potential Indications

- Failure to wean from cardiopulmonary bypass
- Drug overdose with profound cardiac depression
- Myocarditis
- Early graft failure: post heart transplant
- Idiopathic acute heart failure as a bridge to decision
- Pulmonary embolism
- Cardiac or major vessel trauma
- Pulmonary hemorrhage
- Pulmonary trauma
- Acute anaphylaxis
- Peri-partum cardiomyopathy
- Sepsis

Contraindications

Absolute:

- Non-recoverable heart function and not a candidate for transplant or VAD
- Non-recoverable respiratory disease and not a candidate for transplant
- Ebola

Relative:

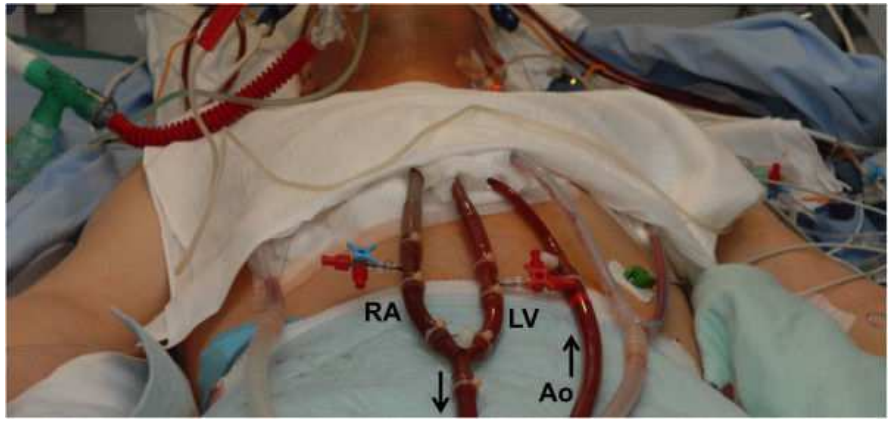
- Mechanical ventilation at high settings for ≥ 7 days
- Prolonged CPR > 45 mins
- Major pharmacologic immunosuppression
- Coagulopathies
- Irreversible MODS (chronic)
- Advanced age >70

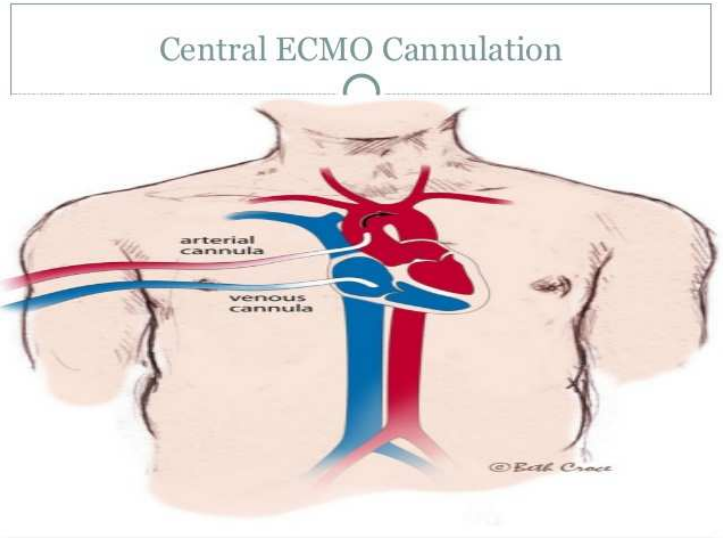
VA ECMO Cannulation

Venous Cannula Sites (Drainage)	Arterial Cannula Sites (Reinfusion)
• R/L Femoral Vein • Right IJ	• R/L Femoral Artery • RCCA (neonates) • Axillary Artery
• Right Atrium	• Aorta

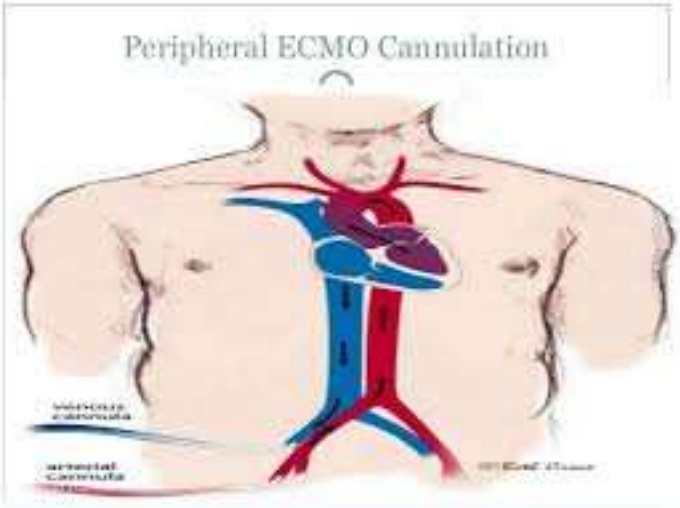
Cannulation Techniques

Central Cannulation





Peripheral Cannulation



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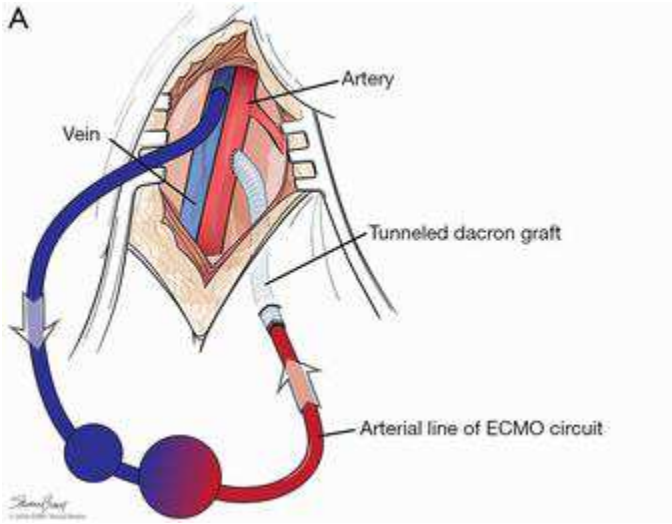
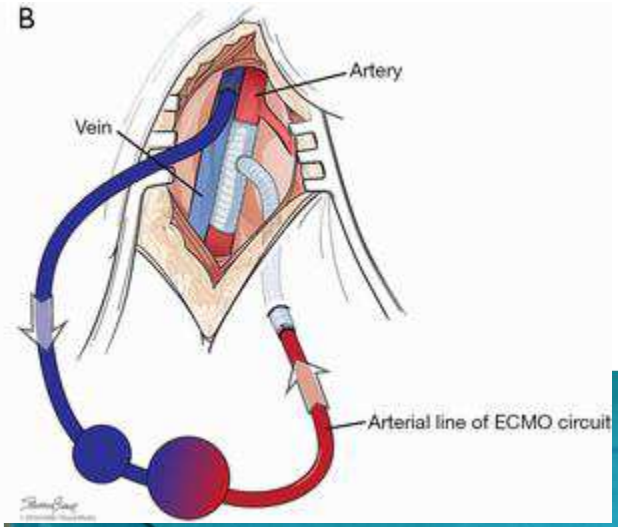
VA ECMO Complications: Distal Perfusion





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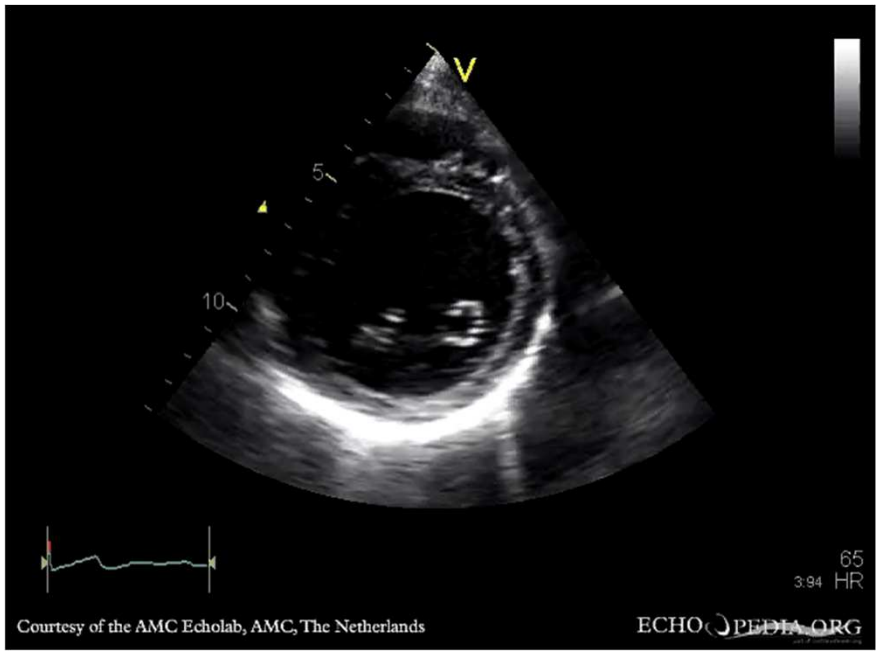
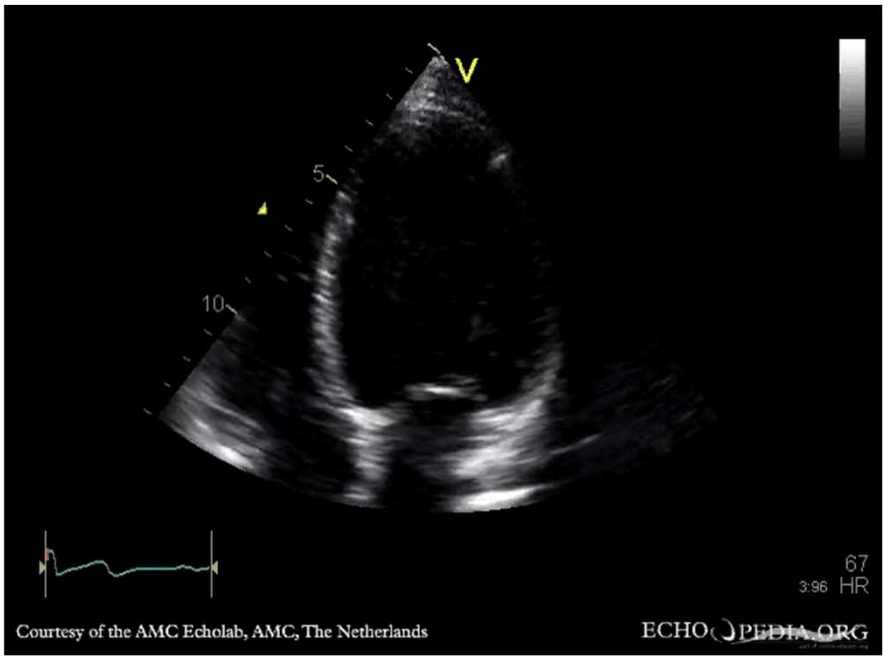
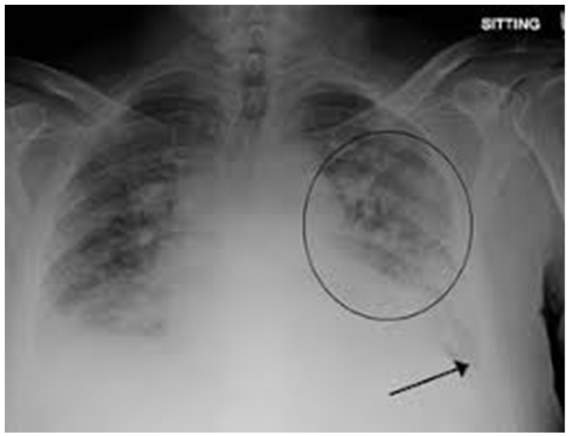
VA ECMO Complications: LV Decompression







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VA ECMO Complications: LV Decompression

ECMO will never capture 100% of cardiac output

If LV is failing, this can result in LV distention

- Distention results in compression of myocardial capillaries = myocardial ischemia.

Occurs in 15-20% of VA ECMO runs

Treatment: LV decompression

- Surgical drain
- Impella
- IABP

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VA ECMO Complications: North-South Syndrome

- A phenomenon in fem-fem cannulation of VA ECMO with recovery of myocardial function with lung dysfunction
  - Native cardiac output competes with ECMO blood flow
    - Oxygen rich ECMO blood is shunted to the lower body while oxygen-poor blood from the LV & lungs perfuses the upper body
- Can lead to cerebral hypoxia
  - Cyanotic upper extremities, Pink lower
- May transition patient to VV ECMO if sufficient myocardial recovery or to a hybrid configuration VVA ECMO

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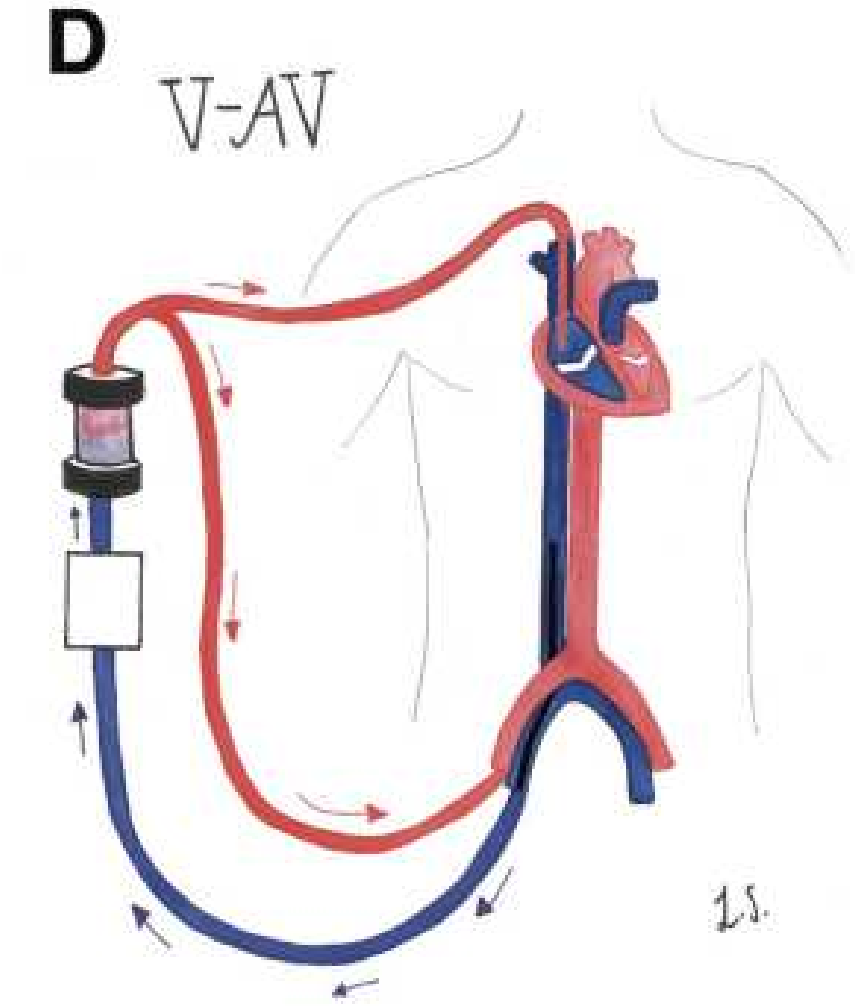
Hybrid ECMO Configuration: V-AV



Veno-Venous (VV) ECMO

- Drainage of deoxygenated blood from a large vein
- Flows through an extracorporeal circuit where the artificial lung oxygenates the blood and removes CO2
- Oxygenated blood returns to the patient to the right atrium
- Does not bypass the heart

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VV ECMO Patient Selection

ARDS
Severe pneumonia
Severe hypoxemia
Status asthmaticus
Pulmonary Contusion
Airway Obstruction
Aspiration Syndromes
Smoke inhalation
Severe air leak syndrome
Alveolar proteinosis

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VV ECMO Cannulation

Drainage Cannula Sites	Reinfusion Cannula Sites
• R/L Femoral Vein	• R/L Femoral Vein
• Right IJ	• Right IJ
• Right Atrium	• Pulmonary Artery

VV ECMO Physiology

- The oxygenated perfusate mixes with the venous blood in the right atrium, raising the O_2 content and lowering the CO_2 content
- Volume of blood removed = Volume returned – no effect on hemodynamics
- VV ECMO does not support perfusion
- Only variable affected is the CO_2 , O2 content of blood
- Tissue O_2 delivery dependent upon an adequate CO

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Advantages of VA & VV ECMO

VA ECMO	VV ECMO
Rest both heart and lungs	Single cannula
Patient is protected from cardiac arrest	Patients own cardiac output with pulsatility
Potential full support 100% dependent on pump flow (if good venous return)	Oxygenated blood to the lungs??
Easier volume management	Potentially more oxygenated blood to coronaries

Disadvantages *of VA & VV ECMO*

VA ECMO

- Potentially less pulsatility
- Requires arterial cannula – Second Cannula
- Obstructed arterial blood flow in that vessel
- Coronary artery blood flow

VV ECMO

- Not protective during cardiac arrest
- More volume sensitive – Volume management
- Does not rest heart
- Mixing – Efficiency of oxygenation - recirculation

ECMO Complications

	Respiratory		Cardiac	
	N	%	N	%
Hemorrhagic: Cannulation site bleeding	1543	12.5%	1924	17.5%
Hemorrhagic: Surgical site bleeding	1232	10.0%	2111	19.2%
Neurologic: Brain death clinically determined	279	2.3%	413	3.8%
Renal: Dialysis required	1197	9.7%	1092	9.9%
Renal: Hemofiltration required	2040	16.5%	1348	12.3%
Cardiovascular: Inotropes on ECLS	4828	39.1%	5749	52.3%
Infectious: Culture proven infection	2114	17.1%	1407	12.8%
Limb: Ischemia	124	1.0%	392	3.6%
Limb: Fasciotomy	35	0.3%	166	1.5%

Complications arising during ECMO support
ELSO report 2017(www.elso.org)

Overall Patient Outcomes

	Total	Surv ECLS		Surv to DC	
Neonatal					
Respiratory	28,271	23,791	84%	20,978	74%
Cardiac	6,046	3,750	62%	2,497	41%
ECPR	1,188	766	64%	489	41%
Pediatric					
Respiratory	6,929	4,579	66%	3,979	57%
Cardiac	7,668	5,084	66%	3,878	51%
ECPR	2,583	1,432	55%	1,070	41%
Adult					
Respiratory	7,922	5,209	66%	4,576	58%
Cardiac	6,522	3,661	56%	2,708	42%
ECPR	1,985	791	40%	589	30%
Total	69,114	49,063	71%	40,764	59%

Increase number of ECMO runs

ECLS Registry Report

International Summary

July, 2016

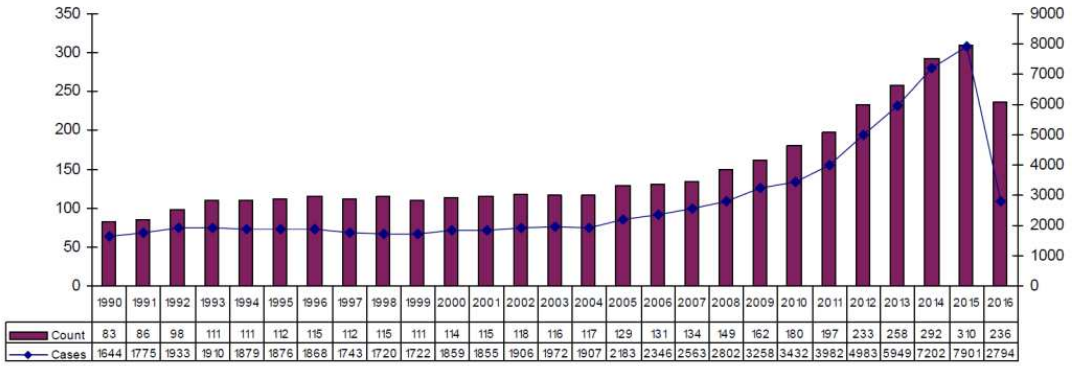
Extracorporeal Life Support Organization
2800 Plymouth Road
Building 300, Room 303
Ann Arbor, MI 48109

Overall Outcomes

	Total Patients	*Survived ECLS*		*Survived to DC or Transfer*	
Neonatal					
Respiratory	29,153	24,488	84%	21,545	74%
Cardiac	6,475	4,028	62%	2,695	42%
ECPR	1,336	859	64%	547	41%
Pediatric					
Respiratory	7,552	5,036	67%	4,371	58%
Cardiac	8,374	5,594	67%	4,265	51%
ECPR	2,996	1,645	55%	1,232	41%
Adult					
Respiratory	10,601	6,997	66%	6,121	58%
Cardiac	9,025	5,082	56%	3,721	41%
ECPR	2,885	1,137	39%	848	29%
Total	78,397	54,866	70%	45,345	58%

Centers

Centers by Year



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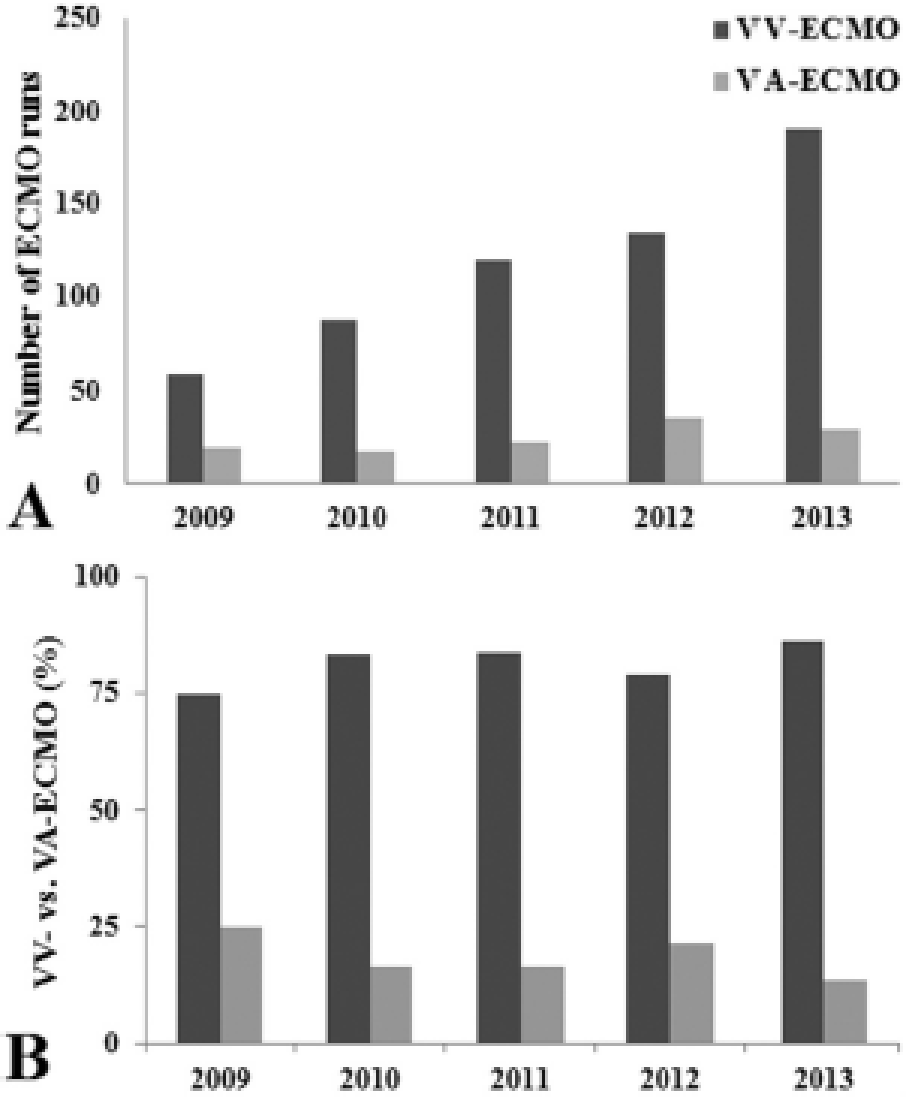
Increased use of VV ECMO



ECLS Registry Report

International Summary

July 2018

Overall Outcomes

	Total Runs
Neonatal	
Pulmonary	30,934
Cardiac	7,794
ECPR	1,718
Pediatric	
Pulmonary	8,820
Cardiac	10,482
ECPR	3,946
Adult	
Pulmonary	16,337
Cardiac	15,942
ECPR	4,952
Total	100,905

ELSO Registry

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*]

- Large retrospective study of ECMO Intl registry
- 1989-2013 period
- 3 age groups –neonatal,pediatric,adult
- Primary outcome-mortality before hospital discharge
- 290 centers
- 56,222 patients(10,588 adults, 30,909 neonates,14,725 children)

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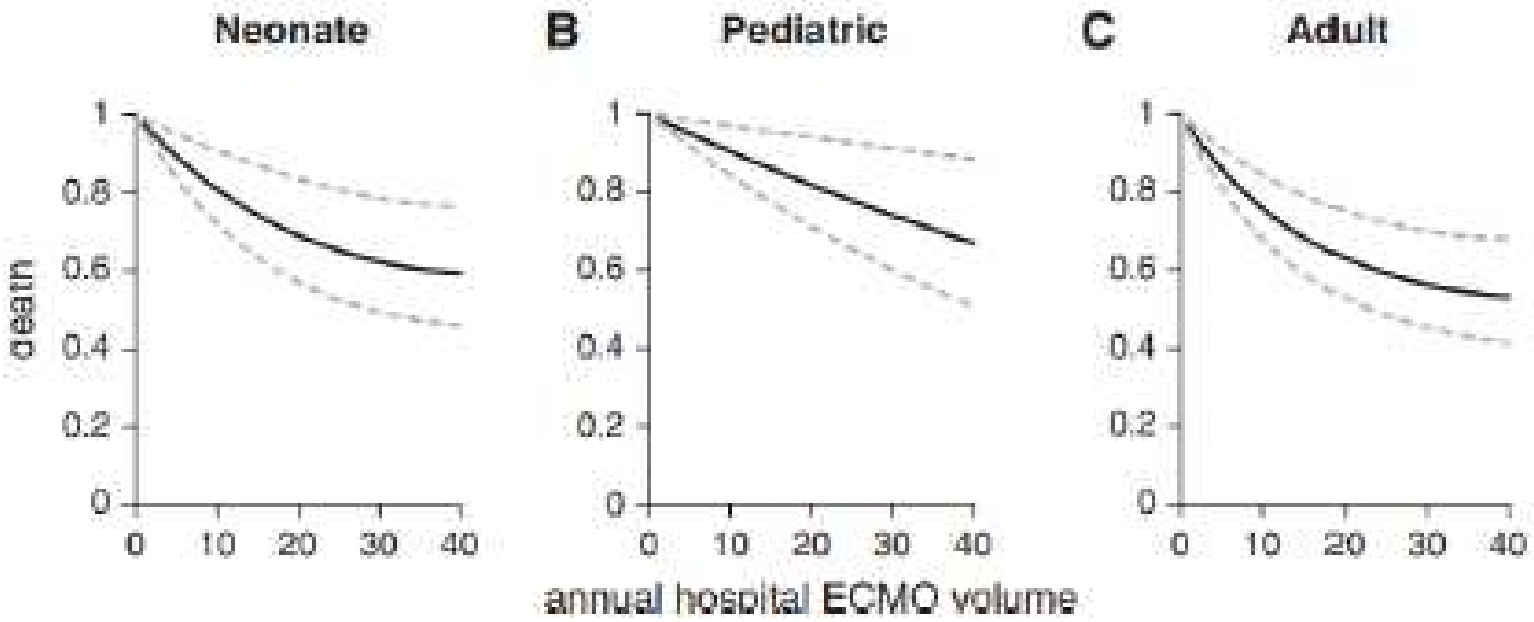
High Volume Centers Associated with Improved ECMO Outcomes



Conclusions: In this international, case-mix-adjusted analysis, higher annual hospital ECMO volume was associated with lower mortality in 1989-2013for neonates and adults; the association among adults persisted in 2008-2013.

Barbaro R et al .AJRCC(2015)

Venovenous Versus Venoarterial Extracorporeal Membrane Oxygenation for Adult Patients With Acute Respiratory Distress Syndrome Requiring Precannulation Hemodynamic Support: A Review of the ELSO Registry

Zachary N. Kon, MD, Gregory J. Bittle, MD, Chetan Pasrija, MD, Si M. Pham, MD, Michael A. Mazzeffi, MD, Daniel L. Herr, MD, Pablo G. Sanchez, MD, PhD, and Bartley P. Griffith, MD

Division of Cardiac Surgery, and Departments of Anesthesiology and Shock Trauma Critical Care, University of Maryland School of Medicine, Baltimore, Maryland

(Ann Thorac Surg 2017;■:■–■)

Retrospective review of Extracorporeal life support (ELSO) registry

2009-2013

Adults (>18yrs)

Primary diagnosis of acute respiratory failure (based on ICD-9 codes) AND required pre-ECMO vasopressor/ionotropic support

Results – Hemodynamics

	VV ECMO (n = 591)	VA ECMO (n = 126)	*p* Value
Pre-ECMO hemodynamics, mm Hg			
SBP	100 (85–119)	87 (73–105)	<0.001
DBP	54 (46–65)	48 (42–59)	0.022
Mean arterial pressure	69 (60–81)	61 (52–73)	<0.001
Pre-ECMO cardiac arrest	52 (8.8)	23 (18.3)	0.003
Inotropic agent requirement	112 (19.0)	44 (34.9)	<0.001
One inotrope agent	100 (16.9)	37 (29.4)	0.003
Two inotrope agents	11 (1.9)	6 (4.8)	0.097
Pressor requirement	276 (46.7)	69 (54.8)	0.116
One pressor	250 (42.3)	55 (43.7)	0.843
Two pressors	26 (4.4)	14 (11.1)	0.008
Total pressors/inotropic agents	1 (1–2)	2 (1–3)	<0.001
Inhaled nitric oxide	114 (19.3)	19 (15.1)	0.313

Results

Table 3. Outcomes

	VV ECMO (n = 591)	VA ECMO (n = 126)	*p* Value
Complications			
Hemolysis	43 (7.3)	16 (12.7)	0.050
Stroke	35 (5.9)	11 (8.7)	0.166
AKI (serum creat > 3)	70 (11.8)	14 (11.1)	0.880
New dialysis requirement	53 (9.0)	15 (11.9)	0.316
Cannula site bleeding	103 (17.4)	24 (19.0)	0.700
GI bleeding	29 (4.9)	11 (8.7)	0.131
Pulmonary hemorrhage	49 (8.3)	12 (9.5)	0.602
Survival to discharge	343 (58.0)	54 (42.9)	0.002

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Results – Multivariate analysis

Table 4. Multivariable Regression Model of Survival to Discharge

	OR	95% CI	*p* Value
VV ECMO	1.944	1.231–3.068	0.004
Age	0.978	0.968–0.989	<0.001
Days of mechanical ventilation	0.998	0.997–0.999	0.001
pH	3.980	1.312–12.071	0.015

Study Conclusions

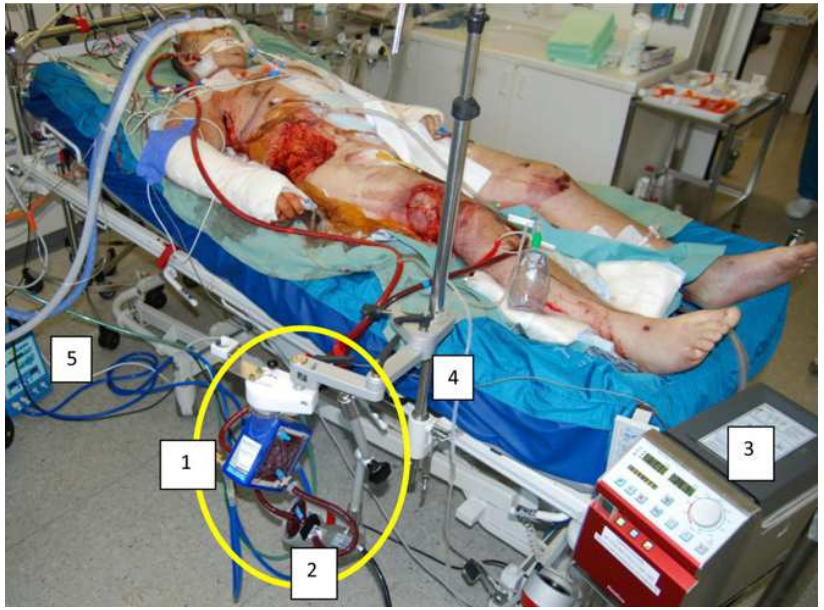
- In patients requiring pre-ECMO vasopressor or inotropic support, the use of VV ECMO is associated with improved survival to discharge
  - No difference in complications
  - 4% conversion of VV to VA ECMO
- VV ECMO, younger age, fewer days of pre-ECMO mechanical ventilation and pre-ECMO pH associated with improved survival.

ECMO in Trauma

- ARDS develops in 5-10% of trauma admissions
  - Up to 20% of patients in shock or requiring emergency surgery
  - ? Better prognosis
    - Younger age
    - Underlying healthy lung parenchyma
    - Reversible disease process
- ARDS in trauma population carries a mortality of 10-20%

ECMO in Trauma

- Limited experience – small case series
- Previous contraindications: ICH, need for additional surgeries, non operative solid organ injuries
- Barriers to ECMO in trauma
  Anticoagulation
  Anticoagulation
  Anticoagulation
  Prothrombotic state



Increased Incidence of ECMO in Trauma

TABLE 1. ECLS Runs for Trauma and Indication (Respiratory, Cardiac, E-CPR)

Year ECLS	All ECLS Patients	Respiratory	Cardiac	E-CPR
1993–1995	2	2	0	0
1996–2000	15	11	2	2
2001–2005	42	39	2	1
2006–2010	47	41	2	4
2011–2016	173	154	14	5
Total, 1993–2016	279	247	20	12

ECLS increased significantly in recent years, with most cases requiring respiratory support.

Swol et al.
J Trauma Acute Care Surg
Volume 84, Number 6

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Survival of Trauma Patients on ECMO

ELSO registry review of 279 trauma patients from 1989-2016

TABLE 5. Comparison of Survival Rates in Trauma Patients Versus Other ELSO Registry Cohorts

Diagnosis	n	Average Run Duration, d	Survival to Hospital Discharge
Trauma—total cohort	279	8.8 ± 9.5	61%
Trauma—respiratory support	247	9.3 ± 9.3	63%
ARDS, not postoperative/trauma*	837	13.0	54%
Acute respiratory failure, non-ARDS*	1408	11.5	55%
Viral pneumonia*	926	13.5	65%
Bacterial pneumonia*	1362	10.9	61%
Trauma—cardiac support	20	4.1 ± 4.5	50%
Adult cardiac support*	9025	6.5	41%
Trauma—ECPR	12	6.5 ± 16.8	25%
Adult ECPR*	2885	Not available	29%

*Data from ELSO.[15]

Swol et al
J Trauma Acute Care Surg
Volume 84, Number 6

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Summary

- ECMO is a powerful tool, but there must be a **destination**
- Indications and contra-indications are relative
- Call early!!!
- ECMO volumes are increasing – especially as the indications become more broad
- ECMO improves survival compared with mechanical ventilation in ARDS
- High volume ECMO centers are associated with improved outcomes
- ECMO can be performed in a variety of patient populations, including post operative and trauma patients with good outcomes

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Questions?