Extracorporeal Life Support for Respiratory Failure

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Conflict of interest statement

This is to acknowledge that Manish Mohanka M.D., MPH has disclosed that he does not have any financial interests or other relationships with commercial concerns related directly or indirectly to this program. Dr. Mohanka will not be discussing off label uses in his presentation.

Dr. Mohanka is a Pulmonary and Critical Care Medicine physician, who specializes in care of lung transplantation patients. He completed medical school from Government Medical College and Hospital Nagpur, India in 2000 and joined Masters in Public Health (Epidemiology) at the University of Washington, Seattle. He trained in Internal Medicine at Hahnemann University Hospital in Philadelphia and in Pulmonary Critical Care fellowship at the Cleveland Clinic. He joined the UT Southwestern in 2012 and currently serves as an Assistant Professor of Internal Medicine at Clements University Hospital. He is an integral part of the lung transplant program. He is also actively involved in clinical research in lung transplant.

Purpose and overview:

Extracorporeal life support (ECLS) is a life-support modality for feeling lungs, heart, or both. Since introduction in the 1970s, the technology has involved into an integral part of critical care units over the last decade supporting patients with refractory respiratory failure despite conventional therapies such as mechanical ventilation.

The purpose of this session is to discuss the evolution, and review evidence supporting use of extracorporeal life support in patients with respiratory failure.

Education objectives:

At the end of this lecture, participants will be able to:

A. Describe the principle and basic circuit components of extracorporeal life support

B. Differences between veno-venous (VV) and veno-arterial (VA) Extracorporeal Membrane Oxygenation (ECMO)

C. Indications for consideration of ECMO

Extracorporeal Life Support

Extracorporeal life support (ECLS) is a system that comprises of a blood pump, artificial lung and associated vascular access cannula, capable of generating adequate blood flow rates to support blood oxygenation (in addition to carbon dioxide removal) with or without providing circulatory support.

Extracorporeal life support (ECLS) is an overarching term for a life-support modality used for failing lungs, heart, or both. This includes extracorporeal membrane oxygenation (ECMO) and extracorporeal carbon dioxide removal (ECCO2R) [1,2]

Principle of ECMO

During instances of severe respiratory or cardiac failure, refractory to conventional therapies such as mechanical ventilation, vasopressor support, etc. extracorporeal circuit is used to support the functioning of lung or heart as follows:

1) Desaturated blood is drained from a central vein via a cannula
2) Blood is pumped through an extracorporeal "artificial lung" device where oxygen is added and carbon dioxide is removed
3) Oxygenated blood is returned back to systemic circulation via a central vein (as in VV ECMO), or via an artery (as in VA ECMO)
4) Typical blood flow through the ECMO circuit is 3.5-7 L/min, which allows for adequate gas exchange to support tissue oxygenation[1].

Components of ECMO Circuit:

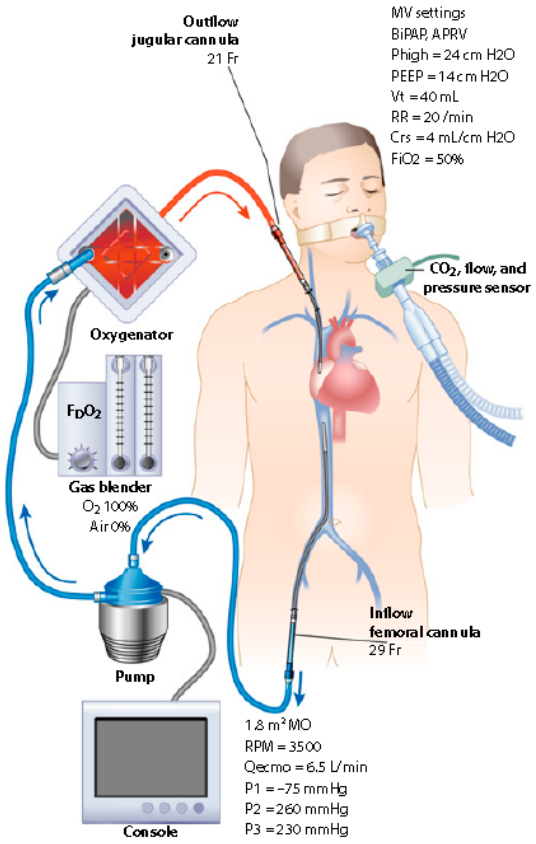
The basic components of an ECMO circuit include:

1) Draining cannula which removes desaturated blood from central veins
2) Centrifugal blood pump, which prompts the blood forward. It is possible to change the blood flow rates to the pump using the console depending on patient needs
3) Console/computer which controls the rate of blood flow through the pump and also displays monitoring parameters
4) Membrane oxygenator or "artificial lung" where gas exchange takes place: The oxygenator comprises of crisscrossing network of hollow tubules through which oxygen-rich exchanging or "sweep gas" flows. Membrane oxygenator also frequently doubles up as heat exchanger through network of hollow tubules carrying heated/cold water to regulate temperature of blood circulating through the ECMO circuit
5) Gas blender, which controls the composition of sweep gas. The composition of "sweep gas" can be controlled with gas blender (FiO2 from 21-100%). The rate of carbon dioxide clearance is

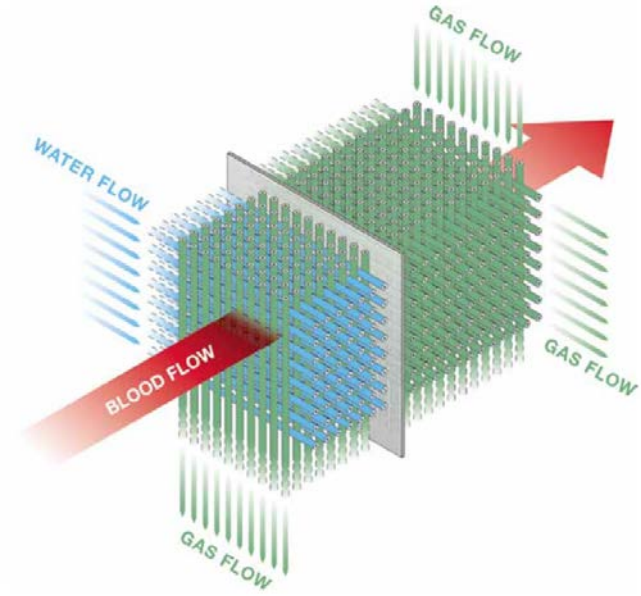
dependent on the rate of sweep gas flow; however near-maximum clearance is usually obtained around 8 to 10 L flow of sweep gas.

6) Return cannula through which blood is prompt back into a central vein (such as in veno-venous ECMO) or into an artery (such as in veno-arterial ECMO)

Monitors in place include blood flow-rate monitors (ultrasound Doppler flow measurements), pressure monitors (for the inflow and outflow cannula), air-bubble detectors (ultrasound), and blood oxygen saturation. The console displays the necessary control and observed parameters needed for patient care needs. [1,3,4]



Components of ECMO Circuit (Veno-venous Configuration)



Functioning of Membrane Oxygenator/ Heat-Exchanger

Indications for use of ECMO in respiratory failure:

The indications for ECMO are support for a failing lung, heart or both, which is refractory to conventional therapies. [1,2]

Depending on patient needs, ECMO circuit can be configured to primarily support either respiratory failure or circulatory failure as follows:

1) Veno-venous ECMO (VV ECMO) circuit returns the oxygenated and carbon dioxide depleted blood back into venous circulation, thereby replacing the function of lungs. Therefore, it is primarily for respiratory failure- hypoxic, hypercarbic or both. Besides, it can be used for respiratory support when “lung rest” is desired such as managing airway stenosis, airway dehiscence or bronchopleural fistula.
2) Veno-arterial ECMO (VA ECMO) circuit returns the blood back to systemic artery under pressurization, thereby providing perfusion pressure for end-organ perfusion. Therefore, it can be used for supporting heart failure- right-sided, left-sided or biventricular heart failure. Common right heart failure etiologies include acute pulmonary embolism or untreated pulmonary hypertension.

ECMO is a life support tool for duration up to 30 days and is not a disease modifying therapy. Therefore, it is used as a "bridge" to destination as below:

1) Recovery: Acute lung/ heart disease when recovery from insult is expected
2) Transplant: For end-stage pulmonary/ cardiac disease
3) Device: To supporting device (such as LVAD, MCS for heart failure)
4) Decision: when diagnosis/ prognosis/ disease reversibility is unclear
5) Extracorporeal CPR: similar to “Recovery”

Historical landmarks in development of ECLS:

Development of Oxygenators: There are 2 main types of oxygenators-“direct-contact” and “membrane”. Direct contact oxygenators are characterized by direct contact of blood with the exchanging gas. Membrane oxygenators are characterized by a thin film of membrane which separates blood and air, and the gas exchange happens by diffusion across the membrane. [5]

Direct contact type oxygenators: Initial experiments towards building an oxygenator involved shaking defibrillated blood with air together in a balloon to demonstrate improved oxygen saturation in 1869 (Ludwig and Schmidt). In the first 2 decades of the 20th Century, several bubble/surface contact oxygenators were designed; however use was limited due to hemolysis, clotting, protein denaturation from interaction of blood with device materials/ air. The problem was partly attenuated by the discovery of heparin by medical student, Jay MacLean from dog heart muscle in 1916. Contact type oxygenators were used in open heart surgery from 1930-1960, with surgery duration usually lasting below 4 hours due to limitation of hemolysis, blood clotting.

Membrane oxygenators: In 1944, Kolff and Berk found that blood circulating in hemodialysis machine became oxygenated, thereby generating interest towards developing a dialysis-like "artificial lung" device that could support a failing lung. In the 1960s and 70s, several membrane oxygenators were designed (Kolobow, Lande-Edwards, Bramson, General Electric-Pierce, others) but were limited by inefficient gas-exchange, plasma leak, clotting. Membrane oxygenators, despite these limitations had the advantage of less hemolysis, clotting, and better fluid-volume control compared to contact oxygenators.

Improvement in technology

The ECMO technology continued to evolve in the late-1980s and 1990s. Several improvements to alleviate problems associated with extracorporeal blood flow were incorporated into newer devices. Prominent changes included development of high-performance membrane oxygenators, which were a network of microporous hollow fibers through which sweep gas flowed. Improvement in materials of fibers allowed for better gas exchange, less plasma leakage, clotting and hemolysis[6]. Transition from roller-type to centrifugal-type pumps also reduced hemolysis. Heparin-coated cannulas were designed to reduce clotting problems.

Evidence for use of ECMO for respiratory failure:

Acute Respiratory Distress Syndrome (ARDS)

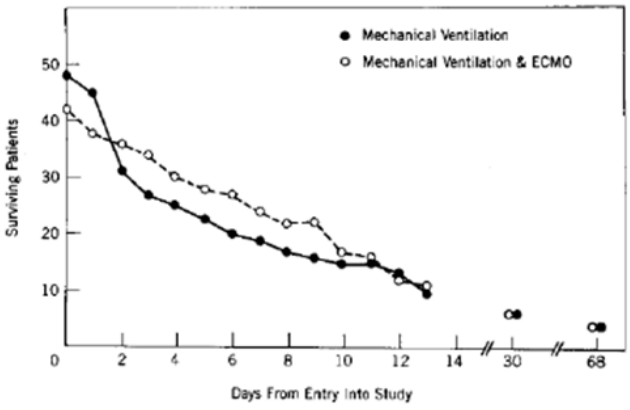
The first successful clinical use of extracorporeal membrane oxygenation in adults was demonstrated by Dr. Donald Hill and colleagues in 1971 when they supported a 24-year-old man with ARDS related to blunt trauma from motor vehicle accident for 75 hours continuously[7].

NIH trial: ECMO for ARDS

Anecdotal reports of successful use of ECMO for respiratory failure led National Institutes of Health (NIH) to sponsor the first randomized clinical trial for the use of ECMO in ARDS[8]. It was a multicenter study conducted from 1975-77. Total of 90 patients with severe ARDS needing ventilator support for less than 3-week duration were randomized to receive VA ECMO+ ventilator (n=42), or conventional ventilator support (n=48). Unfortunately, the trial was unsuccessful as nearly 90% patient mortality was seen in each group. Patients died due to progressive respiratory failure and the autopsy revealed progressive ARDS. The ECMO arm additionally suffered blood loss up to 2000 mL/day.

The failure of the trial was attributed eventually to rudimentary equipment, inadequate experience with managing ECMO, choice of VA ECMO for respiratory failure, and a protocol been from ECMO by day 5.

	Patient Outcome		
Therapy*	Dead—Respiratory Improvement Never Occurred	Dead After Respiratory Improvement	Survived After Respiratory Improvement
ECMO and MV	34	4	4
MV (control)	41	3	4



Survival- NIH Trial

Lung protective ventilation and ECCO2R

In the 1980s, there was an increasing awareness of the role of ventilator-introduced volume trauma and barotrauma in the treatment of acute respiratory distress syndrome[9]. These could be reduced with "lung-protective" ventilation strategies such as low tidal volume ventilation and lower respiratory rate. These objectives could be accomplished using a low blood-flow variant of extracorporeal life support

called extracorporeal carbon dioxide removal device or ECCO2R. The primary goal of ECCO2R device was carbon dioxide clearance which could be accomplished at blood-flow below 2 L/min as carbon dioxide is a highly diffuse blood gas. However, low blood flow rate limited ability to provide adequate amounts of oxygenated blood to support body oxygen needs.

In 1986, Gattinoni and colleagues reported results from an observational study for the use of ECCO2R among 43 patients with acute respiratory failure, predominantly ARDS[10]. Investigators used "ECMO entry criteria" to identify ARDS patients as a candidate for ECCO2R. The ECMO entry criteria were

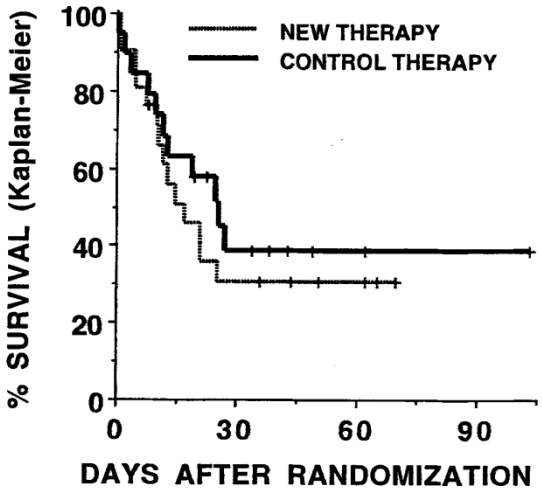
1) Rapid criteria: pO2<50 on FiO2 1.0, PEEP> 5 for 2 hours (n=5), or
2) Slow: pO2 below 50 on FiO2 >60%, PEEP>5 for 12 hours (n=38)

The study reported 49% patient survival at hospital discharge, however there was no control group. Patients were on mechanical ventilation for average of 9 days before extracorporeal support, work on FiO2 ranging from 0.72-0.85, PEEP 11-13. During extracorporeal support, patients had an average of 1800 mL blood loss a day.

Randomized trial for ECCO2R

Spurred by higher survival demonstrated by Gattinoni and colleagues, a randomized trial evaluating the role of ECCO2R in ARDS was performed by Morris and colleagues at the University of Utah[11]. Investigators recruited 40 patient's with ARDS, ratio of arterial/alveolar oxygen pressure <0.2 on mechanical ventilator for less than 3 weeks. Patient were randomized to ECCO2R+ low-frequency mechanical ventilation (n=18) versus conventional mechanical ventilation (n=22).

Patients were on mechanical ventilation for mean duration of 7.7 days prior to extracorporeal support. Mean FiO2 before enrollment was 90%, PaO2/FiO2 ratio 63 and PEEP 16. No significant 30-day survival advantage was noted in the ECCO2R group (33% versus 42%). Besides, ECCO2R group required blood transfusions amounting to an average of over 800 mL/day.



ECCO2R trial: 30-day survival

The authors concluded that carbon dioxide clearance and protective lung ventilation was not adequate to improve survival outcomes with ARDS.

Successful clinical trials for ECMO use in children

Contrary to adult population, clinical trials for the use of ECMO in neonates and pediatric groups were met with success. The first use of ECMO in children was reported in 1975 for a neonate (famous as Esperanza case) who underwent closure of patent ductus arteriosus and was successfully weaned off after being supported with VA ECMO for 7 days[12]. This was followed by a clinical trial involving 12 infants with neonatal respiratory distress who were successfully bridged with ECMO (100% survival)[13]. Another trial in 1989 reported significantly better survival (97% versus 60%) with ECMO support for neonates with primary pulmonary hypertension of newborn[14]. A large multicenter trial (UK Collaborative ECMO Trial, 1996) with 185 neonates with respiratory distress was stopped early due to significantly reduced hospital mortality (30% versus 59%) in the ECMO group. By 1990, ECMO was already being used as a standard of care in several pediatric ICUs[15].

ECMO in adults

With the failure of NIH trial and ECCO2R trial, the use of ECMO in adults was relegated to few centers around the world as “rescue therapy” for refractory respiratory failure. Case-reports and small case-series of successful use of ECMO continued to be reported[8,11].

The largest case-series for use of ECMO as "rescue therapy" for ARDS was reported from University of Michigan in 2004. Hemmila and colleagues [16]used ECMO for 255 patients, with severe ARDS, A-a gradient over 600 (approximate PaO2/ FiO2 ratio below 60) despite optimal medical management including lung protective ventilator settings, heavy sedation, neuromuscular blockade if needed, prone position besides other supportive therapies. The cause of ARDS was pneumonia (55%), trauma (12%) and sepsis (6%). Patients were on ventilator for average of 3.8 days +/-3.3 days prior to ECMO support. PaO2/FiO2 ratio was 55+/-15 and PEEP was 13 +/-4. ECMO was used in both VV configuration (60%) and VA consolidation (40%). Survival was associated with lower age, male gender, pre-ECMO ventilator days, pre-ECMO pH>7.1 and higher PaO2/FiO2 ratio.

Year 2009 and ECMO

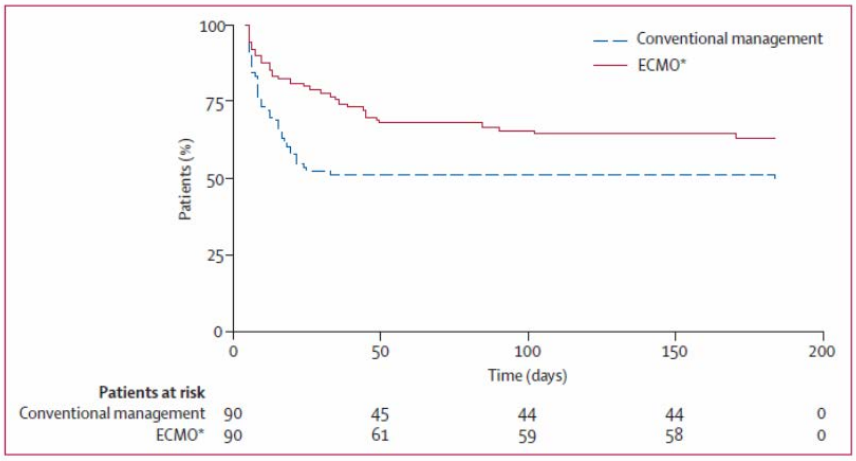
Year 2009 marked paradigm shift in the use of ECMO for ARDS due to 2 events. A successful randomized trial was published from UK (CESAR trial). Unfortunately at the same time, a pandemic of H1N1 Influenza A affected worldwide population resulting in high mortality due to ARDS.

The CESAR trial (2009)

University of Leicester, UK conducted a multicenter randomized control trial involving 68 centers for use of ECMO versus conventional ventilation among 180 patients with severe ARDS within 7 days of intubation[17]. Severe ARDS was defined as patients with acute hypoxemic respiratory failure with a Murray lung injury score>3, or uncompensated hypercapnia with pH<7.2. (Murray lung injury score is a measure of severity of ARDS described in 1988. It is a composite score using lung compliance, ventilator settings, blood gas oxygenation and radiology).

Patients were randomized to conventional mechanical ventilation or transfer to ECMO-capable center. The primary endpoint was death or severe disability at 6 months, defined as "confinement to bed and inability to wash or dress alone". After transfer to ECMO capable center, ECMO group was reassessed for need of ECMO. In the ECMO group, 68/90 (75%) received ECMO. Out of the other 22, 16 improved on ventilator, 3 patient's diet before transfer, 2 died during transfer, and one had heparin intolerance. Analysis was performed by intention to treat.

ARDS was caused by pneumonia (60%), sepsis (28%), trauma (7%). PaO2/FiO2 ratio was 35, PEEP was 14. Chest x-ray infiltrate 3.6 quadrants. Compliance 26 mL/cm water pressure, pH 7.1. About 30% of patients had 3 or more organ failure.



CESAR Trial: Severe Disability-Free Survival

Investigators found significant difference in primary outcome, death/disability at 6 months (37% versus 53%, p= 0.03). Mortality at 6-months was not significantly different (37% versus 45%, p= 0.07). The main difference between cause of death among ECMO and conventional ventilator group was respiratory failure (9% versus 27%)

H1N1 influenza pandemic of 2009

The H1N1 influenza affected 61 million people, and resulted in 275,000 hospitalizations causing 12,500 deaths in the US alone. This was caused due to antigenic shift of the influenza virus. Unlike previous

strains of influenza virus, H1N1 also targeted young and otherwise healthy individuals and resulted in high mortality rates (4-5 deaths/100,000 vs. 0.2-0.4 deaths/ 100,000). [18]

The earliest report of favorable outcomes with use of ECMO for H1N1 –related ARDS came from Australia/ New Zealand[19]. Investigators reported use of ECMO for 68 patients with ARDS (VV configuration 63, VA configuration 5) with very severe respiratory failure, PaO2/FiO2 ratio 56, PEEP 18 and Murray score 3.8. ICU discharge was reported at 71%, hospital discharge at 47%. With severity of disease, this report was published while 24% of patients were still in the hospital. Hospital mortality was reported at 21% with death of 7/11 patients being related to bleeding/intracranial hemorrhage.

Subsequently, similar survival rates for severe ARDS associated with H1N1 influenza A were reported from other centers around the world- the United Kingdom[20], France[21] and Italy[22]. Survival in these series was reported in 64-73% range, which was promising compared to expected survival below <40% for similarly ill patients with ARDS. Notably, despite higher rates of survival than expected, the French group did not find significant survival benefit for ECMO group compared to a propensity score-matched control group who did not receive ECMO.

EOLIA Trial (2018)

EOLIA was an international multicenter randomized control trial aimed at demonstrating the efficacy of ECMO in care of very severe ARDS patients[23]. The trial enrolled 249 patients with very severe ARDS, on ventilator for less than 7 days. This trial standardized strict entry criteria for ventilator settings. Other supportive measures such as use of inhaled nitric oxide, neuromuscular blockade and prone position were encouraged prior to randomization.

1) PaO2/FiO2< 50 mm Hg for more than 3 hours
2) PaO2/FiO2<80 mm Hg for more than 6 hours
3) pH< 7.25 with PCO2> 60 mm Hg for more than 6 hours

Patients were randomized to receive VV ECMO versus conventional treatment (control group). However, with previous studies showing possible survival advantage to using ECMO for ARDS, this study allowed for crossover of conventional ventilation control group to ECMO for refractory respiratory failure.

The primary endpoint was mortality at 60 days and secondary endpoint was treatment failure, defined as death or crossover to ECMO. Study excluded patients with chronic lung disease and those needing ventilator for over 7 days prior to study recruitment. Study also excluded patients who had concurrent circulatory failure and needed support with VA ECMO, BMI greater than 45, though suffering from irreversible neurologic injury or had moribund condition.

ARDS was caused by pneumonia (64%) and patients were on mechanical ventilation for a median of 34 hours. PaO2/FiO2 ratio was 73, PEEP was 11.8 and mean lung compliance was 25 mL/cm H2O pressure.

ECMO group consisted of 124 patients and the control group consisted of 125 patients. From the control group, 35 patients received rescue ECMO, of which 15 eventually survived (42%). Analysis was done by intention to treat.

The mortality at 60-day was not significantly different between the 2 groups (35% versus 46% p=0.09). However, secondary endpoint of treatment failure was highly significant in favor of ECMO (35% versus 58%, p<0.001).

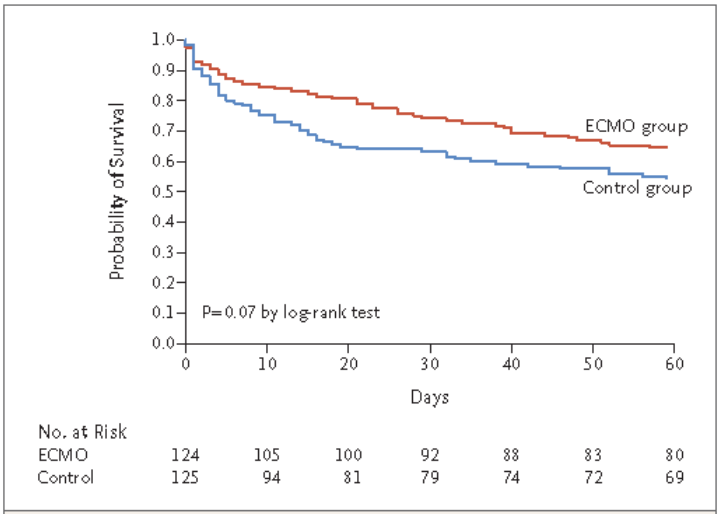


Figure 2. Kaplan–Meier Survival Estimates in the Intention-to-Treat Population during the First 60 Days of the Trial.

EOLIA: 60-day Survival

Patients in ECMO group also had significantly higher vasopressor and renal replacement-free days. However ECMO group had significantly higher incidence of severe thrombocytopenia (27% versus 16%) and required more blood transfusion due to bleeding (46% versus 20%). Risk of ischemic stroke was higher in the conventional mechanical ventilation group (0% versus 5%).

Predictors of survival for patients needing ECMO support

Is a population that benefits most with ECMO?

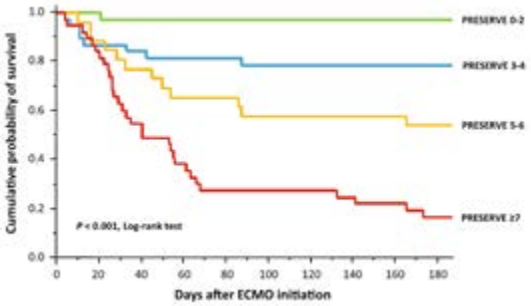
ECMO is a scarce resource available in select hospitals and medical centers, thereby often requiring inter-hospital or intra-hospital transfers. Patients are at risk of mortality during transportation as well as complications related to ECMO such as vascular injury, infections, blood clots, bleeding, etc. Besides it is resource intensive needing comprehensive ICU care and high health care costs, approximating 20-$40,000 a day.

PRESERVE Score

In 2013, Schmidt and colleagues reported data from retrospective case-control design study involving 3 intensive care units in France, looking at predictors of 6-month mortality among patients needing VV ECMO for ARDS[24]. Investigators reviewed charts of 140 patients who were treated with ECMO between 2008 and 2012. ARDS was caused due to bacterial pneumonia and 45% of patients, Influenza A in 26% and perioperative pneumonia and 17% of patients. The investigators devised a PRESERVE score system ranging from 0-14. Patients with lower scores had higher orders of survival at 6 months.

Table 4 The PRESERVE score calculated with parameters available at the time of decision to initiate ECMO

Parameter	Score
Age (years)	
<45	0
45–55	2
>55	3
Body mass index >30	−2
Immunocompromised	2
SOFA >12[a]	1
MV >6 days	1
No prone positioning before ECMO	1
PEEP < 10 cm H_2O	2
Plateau pressure >30 cm H_2O	2
Total score[c]	0–14



PRESERVE Score for 6-Month Mortality Predictors with VV ECMO

RESP Score: In a subsequent paper in 2014, Schmidt and colleagues used the Extracorporeal Life Support Organization (ELSO) international registry database (2000-2012) to investigate pre-ECMO variables associated with hospital discharge[25]. This was a retrospective case-control study and investigators devised the "RESP" score, including several pulmonary and non-pulmonary predictive variables. The score ranged from -22 to 15, with higher scores predicting better survival. The authors validated the study variables using patient population for the PRESERVE score study from 2013.

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%

RESP Score for Survival at Hospital-Discharge after ECMO

Use of ECMO for Massive Pulmonary Embolism

No randomized clinical trials have been performed evaluating the use of ECMO for the treatment of acute massive pulmonary embolism. Starting mid-1990s, several case reports and case series were published describing successful use of ECMO for massive PE. Yusuff and colleagues conducted systematic review of 19 published articles spanning 1995-2014, including a total of 78 patients, average age 49+/-12 years[26]. ECMO support was provided for a mean duration of 4.4 days. Hemodynamic support with ECMO was combined with targeted therapy for pulmonary embolism including systemic thrombolysis (47%), catheter directed thrombolysis (29%), and surgical embolectomy (26%). Investigators reported an overall survival of 70%.

Subsequently, Ain and colleagues [27]reported retrospective data from Massachusetts General Hospital for the duration 1994-2014. In January 2011, the institution started aggressively pursuing emergent ECMO use for acute high-risk pulmonary embolism, defined as patients with shock or cardiac arrest. Of

the 60 patients with high-risk PE, there were 31 in the pre-ECMO era (n=31) and 29 in the post-ECMO era (n=29). The mean patient age was 56 years, 48% males and RV dysfunction was noted in 89% patients on echocardiogram. Vasopressor support was needed for 93% patients. Nearly 60% of patients had central pulmonary emboli. ECMO was used in 13 out of 29 patients in the post- ECMO era, with mean duration from presentation to cannulation of 6 hours. Average duration of ECMO cannulation was 4 days. Systemic thrombolysis (35% vs. 7%) was more common in the pre-ECMO area and catheter directed thrombolysis in the post ECMO area (24% vs 3%). Investigators reported significantly better 30-day survival in the post ECMO area 17% vs. 41% (p=0.04).

Pasrija and colleagues [28]reported single center retrospective chart review data from University of Maryland for the duration 2014-16. The institution pursued early and aggressive VA ECMO for massive PEs, defined as patients with CT scan confirmed pulmonary embolism with cardiac arrest or shock. Investigators found 20 patients, 5 with cardiac arrest, mean age 47 years who were managed with VA ECMO and systemic anticoagulation. As per protocol, patients were assessed for hemodynamic stability and right ventricular function on echocardiogram between days 3-5 after initiating ECMO support. Thereafter, a trial of ECMO wean "ramp trial or ramp study" was attempted followed by decannulation if hemodynamically stable (8/20 patients). For patients unable to tolerate weaning off of ECMO support, surgical embolectomy was performed (11/20 patients). Investigators reported 90-day survival at 95%.

Contraindications to ECMO

Absolute contraindication: Irreversible underlying lung or heart failure, when patient is not a candidate for transplantation[1,2]

Relative contraindications:

1) Overall poor prognosis and/or recovery potential: Examples such as moribund state, devastating neurological injury such as, advanced dementia or stroke, untreatable terminal disease such as advanced malignancy, cirrhosis, etc.
2) Intolerance for anticoagulation, bleeding diathesis
3) Vascular access problems

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