



Extracorporeal Life Support (ECLS)

Extracorporeal Life Support (ECLS) provides temporary support for patients with potentially reversible acute heart or lung failure that fails to respond to maximal conventional therapy. Venous blood is aspirated from the patient using a centrifugal pump to an external circuit and a gas exchange device (oxygenator) where blood is enriched with oxygen (O_2) and carbon dioxide (CO_2) is removed. The blood is then pumped back to the patient's venous or arterial circulation. ECLS is also known as extracorporeal membrane oxygenation (ECMO) and the terms are used interchangeably in the literature.

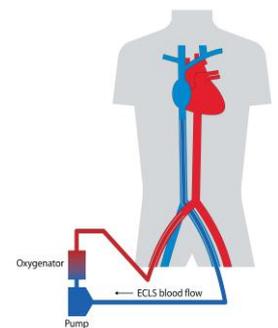
Types of ECLS

Depending on the application, ECLS can be used in the following modes:

- Cardiac ECLS, also called Venous-Arterial ECLS
- Respiratory ECLS, also called Venous-Venous ECLS
- Extracorporeal Carbon Dioxide Removal (ECCO₂R):
 - Low Flow Venous-Venous ECLS
 - Arterio-Venous (pumpless)

Cardiac ECLS or Venous-Arterial (VA) ECLS

Venous blood is aspirated from the vena cava or right atrium (RA), passes through the pump and oxygenator and is pumped back to the aorta. The return arterial cannula may be placed in a peripheral (femoral artery) or central (ascending aorta) location. VA ECLS provides support for severe cardiac failure (often with associated respiratory failure).



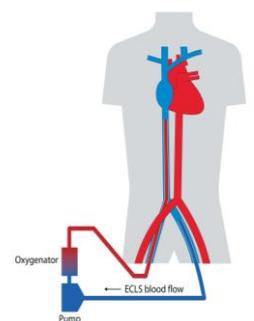
Venous – Arterial ECLS
(Percutaneous Cannulation)

Respiratory ECLS or Venous-Venous (VV) ECLS

Venous blood (>1.5L/min) is aspirated from the vena cava or RA, passes through the pump and oxygenator and is then pumped back to the RA. VV ECLS provides support for severe respiratory failure, there is no direct cardiac support with VV ECLS. VA ECLS can also be used for primary respiratory failure in patients with some degree of concomitant cardiac failure.

There are two methods of cannula placement for VV ECLS:

- **Two-site VV ECLS:** there is a separate access and return cannula (e.g. internal jugular and femoral vein).
- **Single-site VV ECLS:** a dual lumen veno-venous cannula (DLVV ECLS) is placed in a single vessel, (e.g. right internal jugular)





vein). In the dual lumen bi-caval cannula, venous blood is aspirated from the superior and inferior vena cava through one lumen and pumped back to the RA via the second lumen. The design of the cannula is such that mixing of oxygenated and deoxygenated blood (re-circulation) is minimised.

Veno – Venous ECMO
(Percutaneous Cannulation)

Extracorporeal Carbon Dioxide Removal (ECCO₂R)

There are two forms of ECCO₂R, pump-driven low flow VV ECLS or pumpless arterio-venous (AV) ECLS.

- ***Pump-driven low flow VV ECLS for ECCO₂R:***

Venous blood (<1.5L/min) is aspirated from a large vein, passes through the pump and oxygenator where CO₂ is eliminated and is then pumped back to a vein. The low blood flow in this form of ECCO₂R limits oxygen uptake and so oxygenation depends on native lung function. Vascular access can be achieved by either two-site venous cannulation or single-site venous cannulation using a dual lumen cannula.

- ***Pumpless Arterio-Venous (AV) ECLS for ECCO₂R:***

Arterial blood from the femoral artery passes through the membrane oxygenator and is returned to the femoral vein. The flow of blood (usually < 1.5L/min) is driven by the patient's own arterial blood pressure. This system (interventional lung assist or NovaLung) is useful for hypercarbic patients that are not responding to conventional support (mechanical ventilation). The low blood flow through the device limits the uptake of oxygen and therefore is more suitable for CO₂ clearance rather than oxygenation.

The absence of a pump in the AV ECLS system means there is no negative pressure in any part of the relatively simple circuit. The main advantage of pump-driven low flow veno-venous CO₂ removal over AV ECLS is that it eliminates the need for femoral arterial cannulation and its associated complications (e.g. limb ischaemia, creation of a large AV shunt ~ 25%).

Cardiac or VA ECLS

Veno-arterial ECLS is used for short-term support in patients with severe heart (or heart and lung) failure where volume therapy, vasoactive medication and intra-aortic balloon counter-pulsation have failed to provide adequate systemic perfusion. The decision to deploy VA ECLS is often made emergently in patients with acute circulatory shock not responding to conventional support therapies, cardiopulmonary resuscitation or not weaning from intra-operative cardiopulmonary bypass. If possible, the patient should be reviewed by Cardiology, Cardiothoracic Surgery and Critical Care Medicine prior to deployment of VA ECLS.



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Indices of tissue hypoperfusion include systemic hypotension, mental status changes, oliguria, core-peripheral temperature gradient, skin mottling, myocardial ischaemia and increased serum lactate concentration. In patients with satisfactory arterial oxygenation and haemoglobin concentration, inadequate systemic perfusion can be inferred by mixed venous oxygen saturation less than 70%.

Pathologic conditions that may require VA ECLS:

- Post-cardiotomy cardiogenic shock
- Ischaemic cardiogenic shock
- Witnessed cardiac arrest (ECPR: extracorporeal cardiopulmonary resuscitation)
- Bridge to decision regarding suitability for therapy (e.g. revascularisation)
- Bridge to longer term support (e.g. Ventricular Assist Device [VAD], transplantation)
- Acute decompensation of Dilated Cardiomyopathy
- Acute fulminant myocarditis
- Massive pulmonary embolism
- Valvular heart disease
- Refractory arrhythmia's (VT/VF)
- Massive haemoptysis / pulmonary haemorrhage
- Trauma (e.g. pulmonary / cardiac or major vessel)
- Sepsis with profound cardiac depression
- Overdose of cardiac depressant medication
- Acute graft failure after heart transplantation
- Anaphylactic shock
- Congenital cardiac anomalies

Contraindications for Cardiac ECLS:

- Progressive non-recoverable cardiac failure, not amenable to transplantation or VAD
- Severe aortic valve regurgitation
- Aortic dissection
- Un-witnessed cardiac arrest (risk of ischaemic hypoxic encephalopathy)
- Advanced malignancy
- Chronic organ dysfunction
- Contraindication to anticoagulation therapy
- Recent spinal cord or central nervous system trauma or haemorrhage
- Age >70 yrs (consider pre-morbid status)
- BMI >30, BMI <15
- Trauma with multiple bleeding sites
- Significant immunosuppression
- Recent diagnosis of haematological malignancy

In an emergency setting, it may not be possible to identify all the conditions that would normally exclude patients from VA ECLS. At the discretion of the Consultant Intensivist,



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Cardiologist or Cardiothoracic Surgeon, VA ECLS may be commenced emergently and if contraindications become obvious at a later time, ECLS should be withdrawn.

Survival Prediction with SAVE-score:

The SAVE-score (Schmidt *et al.*, 2015) was devised to assist clinicians in predicting in-hospital survival for patients receiving ECLS for refractory cardiogenic shock. There are 12 pre-ECLS variables to compute the SAVE-score which ranges from -35 to +17. This tool is intended for use as an adjunct to clinical judgment.

Note:

ECPR patients are excluded from SAVE-score

Parameter	Score		
Acute cardiogenic shock diagnosis group (select one or more)			
Myocarditis	3		
Refractory VT/VF	2		
Post heart or lung transplantation	3		
Congenital heart disease	-3		
Other diagnoses leading to cardiogenic shock requiring VA-ECMO	0		
Age (years)			
18-38	7		
39-52	4		
53-62	3		
≥ 63	0		
Weight (kg)			
≤ 65	1		
65-89	2		
≥ 90	0		
Acute pre-ECMO organ failures (select one or more if required)			
Liver failure ^a	-3		
Central nervous system dysfunction ^b	-3		
Renal failure ^c	-3		
Chronic renal failure ^d	-6		
Duration of intubation prior to initiation of ECMO (h)			
≤ 10	0		
11-29	-2		
≥ 30	-4		
Peak inspiratory pressure ≤ 20 cmH ₂ O	3		
Pre-ECMO cardiac arrest	-2		
Diastolic blood pressure before ECMO ≥ 40 mmHg ^e	3		
Pulse pressure before ECMO ≤ 20 mmHg ^e	-2		
HCO ₃ before ECMO ≤ 15 mmol/L ^e	-3		
Constant value to add to all calculations of SAVE-score	-6		
Total score	-35 to 17		
Total SAVE-score	Risk class	Survival (%)	
Hospital survival by risk class			
> 5	I	75	
1-5	II	58	
-4 to 0	III	42	
-9 to -5	IV	30	
≤ -10	V	18	

An online calculator is available at www.save-score.com

VT, ventricular tachycardia; VF, ventricular fibrillation.

^aLiver failure was defined as bilirubin ≥ 33 μmol/L or elevation of serum aminotransferases (ALT or AST) > 70 U/L.

^bCNS dysfunction combined neurotrauma, stroke, encephalopathy, cerebral embolism, as well as seizure and epileptic syndromes.

^cRenal dysfunction is defined as acute renal insufficiency (e.g. creatinine > 1.5 mg/dL) with or without RRT.

^dChronic kidney disease is defined as either kidney damage or glomerular filtration rate < 60 mL/min/1.73 m² for ≥ 3 months.

^eWorse value within 6 h prior ECMO cannulation.



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ECPR (Extracorporeal Cardiopulmonary Resuscitation):

ECPR refers to deployment of peripheral VA ECLS during continued advanced cardiac life support (ACLS) for refractory cardiac arrest. Although the number of in-hospital cardiac arrest patients in the MUH is relatively consistent each year, ECPR can only be considered when the collapse occurs at a time and place that sufficiently experienced physician and nursing staff are available to initiate ECLS.

Indications for ECPR:

- Age <65 years
- In-hospital witnessed cardiac arrest; experienced ECLS staff are immediately available
- No delay in initiating good quality ACLS from time of collapse
- Unresponsive to ACLS for >30 minutes
- Time from collapse to establishing ECLS likely to be <60 minutes
- Therapy available for likely cause of cardiac arrest:
 - coronary re-vascularisation
 - thrombolytic therapy or thrombectomy
 - refractory dysrhythmia
 - drug overdose

Contraindications for ECPR:

- Contraindication to anticoagulation therapy
- Aortic dissection
- Severe aortic valve regurgitation
- Chronic organ dysfunction
- Advanced malignancy
- Chronic infections
- Terminal illness



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Respiratory or VV ECLS

VV ECLS is indicated in patients with potentially reversible, acute severe lung failure who continue to deteriorate despite optimal conventional support such as 'lung protective' mechanical ventilation (low tidal volumes, limited plateau pressures [Pplat]) or other advanced therapies (prone position, inhaled pulmonary vasodilators, high frequency oscillation). ECLS should be considered before refractory lung failure or multi-organ failure develops.

Pathologic conditions that may require VV ECLS:

- ARDS
- Severe Air Leak Syndrome
- Pulmonary contusion
- Inhalation Injuries (gastric contents, near drowning, smoke)
- Status asthmaticus,
- Airway Obstruction
- Bridge to lung transplantation
- Acute graft failure following lung transplant
- Alveolar proteinosis

Standard criteria for starting VV ECLS:

1. Murray score >3 (see below)
2. Hypoxaemia: $\text{PaO}_2/\text{FiO}_2 < 10$ on FiO_2 0.9 or higher for >1 hr
3. Hypercapnia: $\text{PaCO}_2 > 11$ or $\text{pH} < 7.20$ for >1 hr
4. Corrected Minute Ventilation: >10 L/min
(surrogate marker of increased dead space: $\text{Min Ventilation} \times \text{PaCO}_2/5.4$)
5. Pplat >30cmH₂O, in absence of high pleural pressures (e.g. abdominal distension)
6. Static Compliance of respiratory system: <20mls/cmH₂O
7. Less than 7 days of high pressure mechanical ventilation

Murray Lung Injury Score:

Score	0	1	2	3	4
$\text{PaO}_2/\text{FiO}_2$ ratio	>40	30–40	20–30	10–20	<10
Compliance	>80	60–80	40–60	20–40	<20
PEEP (cmH ₂ O)	<5	6–8	9–11	12–14	>15
CXR infiltrates: (quadrants)	none	1	2	3	4

Compliance (mls/cmH₂O) = tidal volume/Pplat – PEEP
Total score/4 = Murray Lung Injury Score

Contraindications for VV ECLS:

- Progressive non-recoverable lung disease, not amenable to lung transplantation



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- Chronic severe pulmonary hypertension with right ventricular failure (consider VA ECLS)
- Severe cardiac failure / Cardiac arrest (consider VA ECLS)
- Advanced malignancy
- Chronic organ dysfunction
- Lung Failure associated with bone marrow transplantation
- Contraindication to anticoagulation therapy
- Recent spinal cord or central nervous system trauma or haemorrhage
- Mechanical ventilation with $FiO_2 > 0.9$ and $P_{plat} > 30$ cmH₂O for > 7 days
- Age > 70 yrs
- BMI > 30 , BMI < 5
- Trauma with multiple bleeding sites
- Significant immunosuppression
- Recent diagnosis of haematological malignancy

In an emergency setting, it may not be possible to identify all the conditions that would normally exclude patients from ECLS. At the discretion of the Consultant Intensivist or Cardiothoracic Surgeon, ECLS may be commenced emergently and if contraindications become obvious at a later time, ECLS should be withdrawn.

Survival Prediction with RESP score:

The RESP score (Schmidt *et al.*, 2014) was devised to assist clinicians in predicting in-hospital survival for patients receiving ECLS for respiratory failure. There are 12 pre-ECLS variables to compute the RESP score which ranges from -22 to +15. This tool is intended for use as an adjunct to clinical judgment.

RESP score



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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 _{CO₂} , mm Hg	
<75	0
≥75	-1
Peak inspiratory pressure, cm H ₂ O	
<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.