AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

The Extracorporeal Life Support Organization Maastricht Treaty for Nomenclature in Extracorporeal Life Support

A Position Paper of the Extracorporeal Life Support Organization

Steven A. Conrad[1], L. Mikael Broman[2], Fabio S. Taccone[3], Roberto Lorusso[4], Maximilian V. Malfertheiner[5], Federico Pappalardo[6], Matteo Di Nardo[7], Mirko Belliato[8], Lorenzo Grazioli[9], Ryan P. Barbaro[10], D. Michael McMullan[11], Vincent Pellegrino[12], Daniel Brodie[13], Melania M. Bembea[14], Eddy Fan[15], Malaika Mendonca[16], Rodrigo Diaz[17], Robert H. Bartlett[18]

[1]Departments of Medicine, Emergency Medicine and Pediatrics,
Louisiana State University Health Sciences Center
Shreveport, Louisiana, USA

[2]ECMO Center, Karolinska University Hospital, and Department of Physiology and Pharmacology, Karolinska Institutet
Stockholm, Sweden

[3]Department of Intensive Care
Hôpital Erasme
Brussels, Belgium

[4]Department of Cardiothoracic Surgery
Maastricht University Medical Centre
Maastricht, The Netherlands

[5]Department of Internal Medicine II
University Medical Center Regensburg
Regensburg, Germany

[6]Department of Cardiothoracic Anesthesia and Intensive Care
San Raffaele Hospital
Milan, Italy

[7]Pediatric Intensive Care Unit
Children's Hospital Bambino Gesù, IRCCS
Rome, Italy

[8]U.O.C. Anestesia e Rianimazione 1
Fondazione IRCCS Policlinico San Matteo
Pavia, Italy

[9]Department of Anesthesiology
ASST Papa Giovanni XXIII
Bergamo, Italy

[10]Department of Pediatrics/Intensive Care
University of Michigan
Ann Arbor, Michigan, USA

[11]Department of Surgery/Cardiothoracic Surgery
University of Washington
Seattle, Washington, USA

[12]Department of Intensive Care
Alfred Hospital
Melbourne, Victoria, Australia

[13]Department of Medicine/Pulmonary, Allergy and Critical Care Medicine
Columbia University College of Physicians and Surgeons
New York, New York, USA

[14]Department of Anesthesiology and Critical Care
Johns Hopkins University School of Medicine
Baltimore, Maryland 21287, USA

[15]Interdepartmental Division of Critical Care Medicine
University of Toronto
Toronto, Ontario, Canada

[16]Division of Pediatric Critical Care
Sheikh Khalifa Medical City
Abu Dhabi, UAE

[17]Division of Cardiovascular Anesthesiology
Clinica las Condes
Santiago, Chile

[18]Department of Surgery
University of Michigan.
Ann Arbor, Michigan, USA

Author contributions: Drafting of the article: SAC and LMB. Critical revision of the article for important intellectual content: FST, RL, MVM, FP, MDN, MB, LG, RPB, DMM, VP, DB, MMB, EF, MM, RD, RHB. Final approval of the article: All authors

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Correspondence to:

Steven A. Conrad, MD PhD
Louisiana State University Health Sciences Center
1501 Kings Highway
Shreveport, Louisiana 71103, USA
Voice +1 318 626 2325
Fax +1 318 626 3892
sconrad@lsuhsc.edu

Keywords: Nomenclature; terminology; extracorporeal life support; extracorporeal membrane oxygenation; extracorporeal carbon dioxide removal; extracorporeal circulatory support

Grant support: Melania Bembea - The National Institute of Neurological Disorders and Stroke of the National Institutes of Health under Award Number K23NS076674

Running title: Terminology for extracorporeal life support

Manuscript descriptor: 2.01 Adherence/Compliance/Self-Regulation

Word count: 1495 (targeting Critical Care Perspective)

Current scientific knowledge: Extracorporeal life support (ECLS) is a rapidly expanding field, with the number of research publications growing accordingly. While there is a generally accepted terminology for ECLS, a consistent guide for terminology and abbreviations does not exist.

What does this manuscript add? This manuscript provides a consistent nomenclature and abbreviations for the description of the practice of ECLS and associated devices and techniques.

Abstract

Extracorporeal life support (ECLS) was developed more than 50 years ago initially with venoarterial (VA) and subsequently venovenous (VV) configurations. As the technique of ECLS has significantly improved and newer skills developed, complexity in terminology and advances in cannula design led to some misunderstanding and inconsistency in definitions both in clinical practice and scientific research. This document is a consensus of multispecialty international representatives of the Extracorporeal Life Support Organization, including the North American, Latin American, European, South and West Asian, and Asian-Pacific chapters, imparting a global perspective on ECLS. The goal is to provide a consistent and unambiguous nomenclature for ECLS and to overcome the inconsistent use of abbreviations for ECLS cannulation. Secondary benefits are ease of multicenter collaboration in research and improved registry data quality and clear communication among practitioners and researchers in the field.

Word count: 137

MeSH keywords: Terminology; Extracorporeal membrane oxygenation; Oygenators, Membrane; Extracorporeal Circulation; Cannula

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Introduction

Extracorporeal therapies for temporary, non-intraoperative support of patients with cardiac and/or pulmonary dysfunction are an outgrowth of cardiopulmonary bypass . The success of cardiopulmonary bypass beginning in 1953 for short term circulatory support did not directly translate to more prolonged support due in large part to the lack of biocompatibility of devices of the time (1). Long term extracorporeal support would await the development of newer technologies and approaches over the ensuing decades. The result is a diversity of approaches to temporary support that is rapidly becoming mainstream in the management of severely ill and injured patients

This diversity has led to the use of terms and abbreviations marked by inconsistency and ambiguity. The first reported application of extracorporeal support in the intensive care unit setting (2) employed extracorporeal membrane oxygenation (ECMO) in post-traumatic acute respiratory failure. While the term ECMO refers to a particular extracorporeal configuration and application for support of cardiopulmonary dysfunction, it became synonymous with the use of any extracorporeal system other than surgical cardiopulmonary bypass. A number of extracorporeal applications have emerged that are not considered ECMO, such as extracorporeal carbon dioxide removal (ECCO2R) for managing hypercapnic respiratory failure or supporting ultraprotective ventilation in acute respiratory distress syndrome, extracorporeal cardiopulmonary resuscitation (ECPR) for maintaining systemic perfusion during cardiac arrest, and extracorporeal interval support for organ recovery (EISOR) for providing perfusion of organs awaiting recovery following declaration of cardiac death. The term extracorporeal life support (ECLS) has emerged to describe the entire family of extracorporeal support modalities for long-term support.

Moreover, cannulation configurations for long term support have substantially evolved over the years, with expanded disease indications and outcome pathways (e.g. bridge to recovery, bridge to transplant, bridge to destination) leading to novel cannulation approaches (3-10). Without a formalized approach to cannulation nomenclature there are inconsistencies in the reporting of ECLS studies.

This document represents a consensus on terms, abbreviations, definitions and cannulation descriptions for extracorporeal life support to establish consistency for clinical and research descriptions. The contributors represent multiple specialties performing ECLS, including cardiothoracic surgery, pediatric surgery, surgical intensive care, anesthesiology, cardiology, pulmonary medicine, medical intensive care, pediatric intensive care, neonatology, and emergency medicine. The contributors also represent the international chapters of the Extracorporeal Life Support Organization, including North American, Latin American, European, South and West Asian, and Asian-Pacific, imparting a global perspective on ECLS. The conclusive meeting among all the contributors to finalize the document, hereby presented, was held in Maastricht, The Netherlands, on the occasion of the 6th Euro-ELSO annual meeting, inspiring the denomination of such a nomenclature by another “Maastricht Treaty” realized for an economical/political context.

The Nomenclature Task Force was assembled by ELSO, and the different definitions were based on reviewing of the literature pertaining to ECLS nomenclature as well as on clinical practice. The consensus statement was determined as the most appropriate approach in the absence of studies evaluating the clarity and strength of different terms used in the setting of ECLS; all definitions were then based on expert opinion. The Task Force conferred by e-mail and

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

agreements were achieved through iterative discussion and debate. Recommendations were unanimously agreed and then approved by the Task Force.

This manuscript is composed of three sections. The first gives terms, abbreviations and synonyms, and definitions used in the practice of ECLS. The second section addresses units of measurement. The third and final section is a nomenclature and taxonomy for the description of cannulas, cannulation configurations, and vascular access sites.

Principal terms, abbreviations and definitions

The terms represent concepts from all aspects of ECLS, and are divided into sections on systems and support modes, cannulation concepts, devices, and circuit operation. An abbreviation is provided for each term if in common use. Each term is qualified by a definition. Synonyms are provided if they have been used historically, but to maintain consistency, they should not be used in lieu of the principal term. A comment may accompany a term to provide additional information or clarification.

Systems and support mode terms are given in Table E1 in the online data supplement. This table provides fundamental definitions of ECLS and related therapies. A support mode is a combination of cannulation configuration, circuit operation with an intended type of organ support. Table E2 in the online data supplement provides terminology for general concepts related to cannulation, including devices, procedures, and general approaches to cannulations. Cannulation specifics are covered later in this document. A terminology section for devices used as part of the circuit used for ECLS is given in Table E3 in the online data supplement. Circuit operation terms and concepts are given in Table E4 in the online data supplement.

Units of measurement

Several units of measurement are used for devices and patient management during ECLS. Table E5 in the online data supplement provides the preferred measurement unit systems for ECLS. Système international d'unités (SI) are preferred over Imperial units and used in most cases, except where manufacturer specifications dictate the unit system.

Configurations for peripheral cannulation

Peripheral cannulation configurations vary in complexity, from simple two cannula configurations for traditional venovenous and venoarterial extracorporeal membrane oxygenation (ECMO) to more configurations, for example, with multiple cannulas and multiple drainage or return sites. There is a need to be able to provide basic cannulation information for clinical purposes that conveys the essential configuration. To meet these objectives, a two-level classification system with increasing levels of descriptive information was developed.

Fundamental to all cannulation abbreviations is the use of a hyphen to distinguish drainage cannulas, on the left of the hyphen, and return cannulas, on the right of the hyphen, with the membrane lung, represented by the hyphen itself. In this approach, the presence of a hyphen differentiates a cannulation configuration from the support modes introduced above.

Level one: Cannula hierarchy

All cannulas contributing to the primary (major) draining and return circuit flow are written in upper case letters, e.g. ‘V-V’ representing venous drainage and venous return for venovenous support (Table E6 in the online data supplement). All cannulas with minor flow for secondary drainage, unloading of specific anatomical location, or to promote distal perfusion are written in lower case letters after the major flow cannula to which side it belongs, e.g. ‘V-Aa’ representing venous drainage, arterial return and secondary arterial return such as for distal perfusion. The use

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

of a dual lumen cannula for venovenous support would be indicated with a preceding '(dl)' abbreviation, e.g. '(dl)V-V'.

A configuration may have two major drainage or return cannulas, in which case a second upper case letter is used to the left of the first upper case letter, or to the right of the second upper case letter, respectively. For example, 'VV-V' would represent venovenous support with two major drainage cannulas and a single return cannula, and 'V-VA' would represent venous drainage and both venous and arterial return (for venovenoarterial hybrid support).

Level two: Cannulation site

The next level of descriptors includes the vessel that is cannulated through the use of subscripted lower-case letters indexing the relevant drainage or return cannulation descriptor. Letters assigned to the different peripheral vessels are given in Table E6 in the online data supplement. Bifemoral cannulation for venoarterial support, for example, would be indicated as 'V_f-A_f' The traditional two cannula venovenous configuration with drainage from the femoral and return to the internal jugular would be indicated as 'V_f-V_j'.

Configurations for central cannulation

Central cannulation involves placement of cannulas in a chamber of the heart or the proximal vena cavae through a median sternotomy or related surgical technique. The general approach for the description of peripheral cannulation is applied to central cannulation, with the exception that the major anatomical sites cannulated for are expressed at two upper case letters, and secondary sites such as venting cannulas are expressed as a lower-case letter (Table E6 in the online data supplement). For example, the common post-cardiotomy configuration for venoarterial support with a left atrial vent would be 'RAv_a-AO'. Left-sided support with drainage from the LV and

aortic return would be ‘LV-AO’, and right-sided support from the right atrium to the pulmonary artery would be ‘RA-PA’.

Conclusions

This classification system for ECLS nomenclature provides a standardized foundation for the description of ECLS application, decreasing ambiguity and providing a consistency for the comparison of clinical reports. It includes an extensive terminology of systems, support modes, devices, units of measurement and cannulation configurations. Given the hierarchical structure of cannulation description, it provides for the inclusion of only as much detail as needed for a given purpose. Based on a defined system, it maintains flexibility to adapt to (many if not all) future developments in cannulation approaches as it supports extensibility.

This nomenclature has limitations. While adequate for supporting descriptions for most clinical applications, it may not meet the needs for research applications where more detail for cannulation configurations such as location of the cannula tip, additional cannulation sites, or non-traditional cannulation configurations, would be desirable. Given its systematic basis, however, it could be extended for such a purpose.

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

References

1. Fortenberry JD, Lorusso R. The history and development of extracorporeal support. In: Brogan TV, Lequier L, Lorusso R, MacLaren G, Peek G, editors. Extracorporeal Life Support: The ELSO Red Book, 5 ed. Ann Arbor, MI: Extracorporeal Life Support Organization; 2017.

2. Hill JD, O'Brien TG, Murray JJ, Dontigny L, Bramson ML, Osborn JJ, Gerbode F. Prolonged extracorporeal oxygenation for acute post-traumatic respiratory failure (shock-lung syndrome). Use of the Bramson membrane lung. *N Engl J Med* 1972; 286: 629-634.

3. Javidfar J, Brodie D, Wang D, Ibrahimiye AN, Yang J, Zwischenberger JB, Sonett J, Bacchetta M. Use of bicaval dual-lumen catheter for adult venovenous extracorporeal membrane oxygenation. *Ann Thorac Surg* 2011; 91: 1763-1768; discussion 1769.

4. Palmer O, Palmer K, Hultman J, Broman M. Cannula design and recirculation during venovenous extracorporeal membrane oxygenation. *ASAIO J* 2016; 62: 737-742.

5. Biscotti M, Lee A, Basner RC, Agerstrand C, Abrams D, Brodie D, Bacchetta M. Hybrid configurations via percutaneous access for extracorporeal membrane oxygenation: a single-center experience. *ASAIO J* 2014; 60: 635-642.

6. Madershahian N, Nagib R, Wippermann J, Strauch J, Wahlers T. A simple technique of distal limb perfusion during prolonged femoro-femoral cannulation. *J Card Surg* 2006; 21: 168-169.

7. Le Guyader A, Lacroix P, Ferrat P, Laskar M. Venous leg congestion treated with distal venous drainage during peripheral extracorporeal membrane oxygenation. *Artif Organs* 2006; 30: 633-635.

8. Skarsgard ED, Salt DR, Lee SK, Extracorporeal Life Support Organization R. Venovenous extracorporeal membrane oxygenation in neonatal respiratory failure: does routine, cephalad jugular drainage improve outcome? *J Pediatr Surg* 2004; 39: 672-676.

9. Avalli L, Maggioni E, Sangalli F, Favini G, Formica F, Fumagalli R. Percutaneous left-heart decompression during extracorporeal membrane oxygenation: an alternative to surgical and transeptal venting in adult patients. *ASAIO J* 2011; 57: 38-40.

10. Kim HE, Jung JW, Shin YR, Park HK, Park YH, Shin HJ. Left Atrial Decompression by Percutaneous Left Atrial Venting Cannula Insertion during Venoarterial Extracorporeal Membrane Oxygenation Support. *Korean J Thorac Cardiovasc Surg* 2016; 49: 203-206.

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Figure Captions

Figure 1 Relationship between ECLS systems, support modes and applications. ECLS extracorporeal life support, ECMO extracorporeal membrane oxygenation, VA ECMO venoarterial extracorporeal membrane oxygenation, VVA ECMO venovenoarterial extracorporeal membrane oxygenation, VV ECMO venovenous extracorporeal membrane oxygenation, ECPR extracorporeal cardiopulmonary resuscitation, EISOR extracorporeal interval support for organ retrieval, ECCO2R extracorporeal carbon dioxide removal, VV ECCO2R venovenous extracorporeal carbon dioxide removal, AV ECCO2R arteriovenous extracorporeal carbon dioxide removal.

Figure 2 Schematic of venoarterial (VA) ECMO (A) and venovenous (VV) ECMO (B) showing typical cannulation sites and direction of blood flow.

Figure 3 Schematic of venovenoarterial (VVA) ECMO (A) and pumpless arteriovenous (AV) ECCO2R showing typical cannulation sites and direction of blood flow.

Figure 4 Schematic of venovenous (VV) ECMO using single-site cannulation with a dual-lumen cannula showing direction of blood flow.

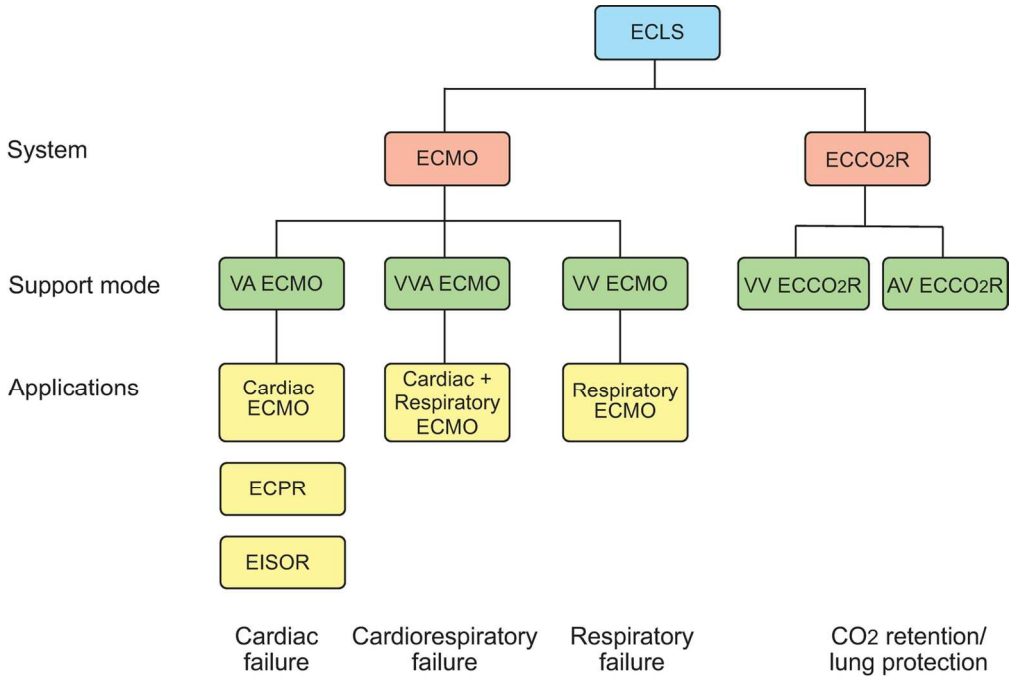

Figure 1. Relationship between ECLS systems, support modes and applications. ECLS extracorporeal life support, ECMO extracorporeal membrane oxygenation, VA ECMO venoarterial extracorporeal membrane oxygenation, VVA ECMO venovenoarterial extracorporeal membrane oxygenation, VV ECMO venovenous extracorporeal membrane oxygenation, ECPR extracorporeal cardiopulmonary resuscitation, EISOR extracorporeal interval support for organ retrieval, ECCO2R extracorporeal carbon dioxide removal, VV ECCO2R venovenous extracorporeal carbon dioxide removal, AV ECCO2R arteriovenous extracorporeal carbon dioxide removal.

137x92mm (300 x 300 DPI)

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

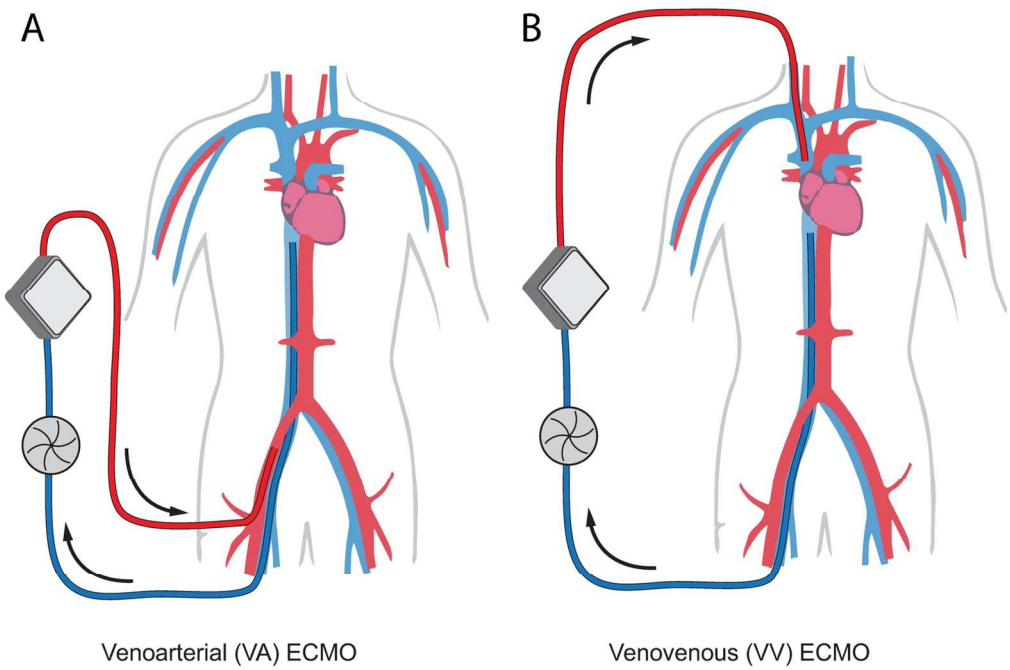

Figure 2. Schematic of venoarterial (VA) ECMO (A) and venovenous (VV) ECMO (B) showing typical cannulation sites and direction of blood flow.

138x91mm (300 x 300 DPI)

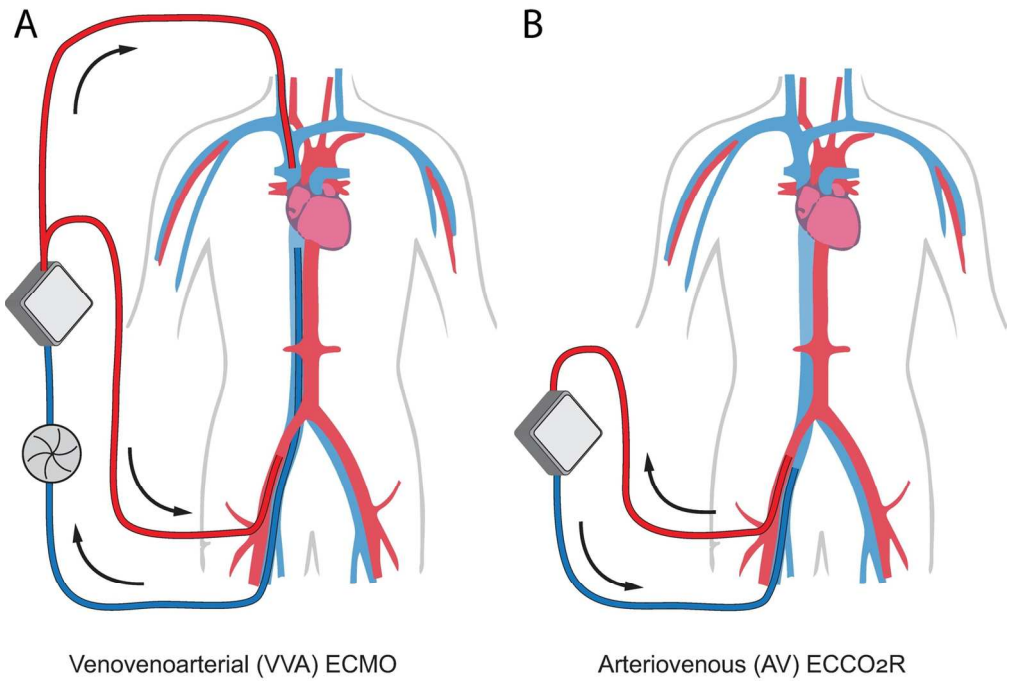

Figure 3. Schematic of venovenoarterial (VVA) ECMO (A) and pumpless arteriovenous (AV) ECCO2R showing typical cannulation sites and direction of blood flow.

139x94mm (300 x 300 DPI)

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

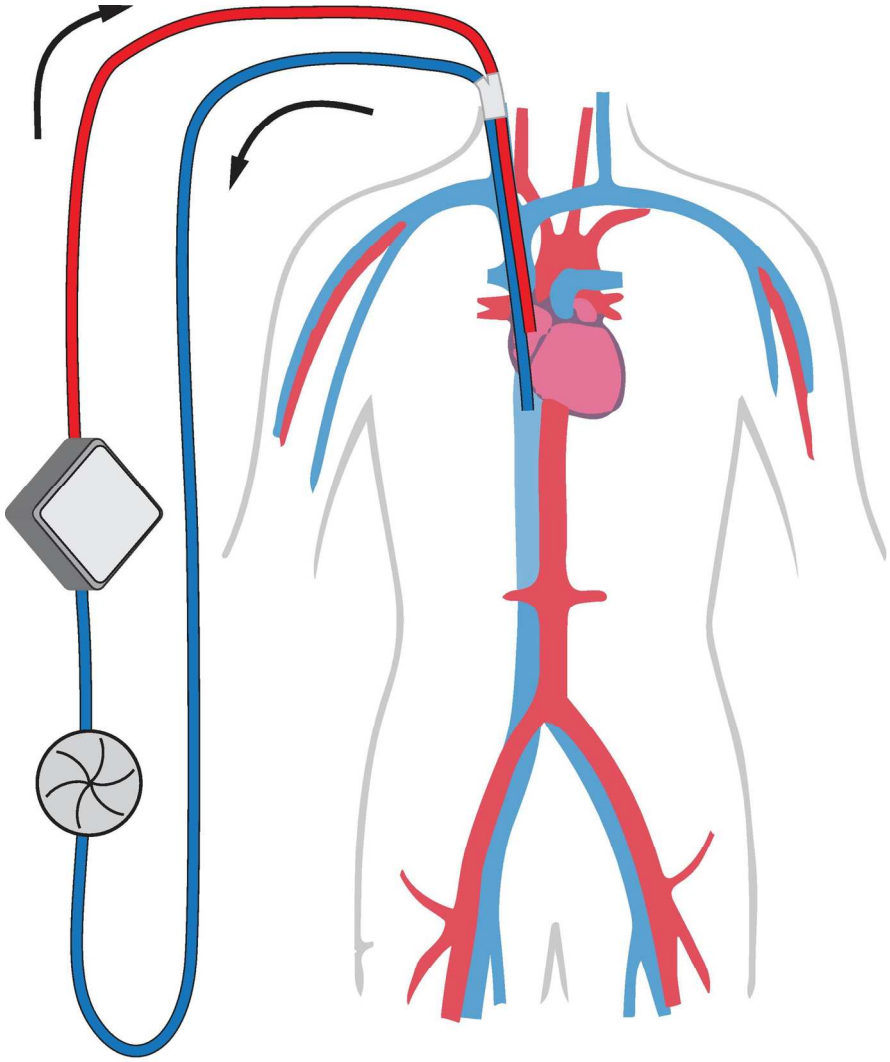

Figure 4. Schematic of venovenous (VV) ECMO using single-site cannulation with a dual-lumen cannula showing direction of blood flow.

137x187mm (300 x 300 DPI)

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

The Extracorporeal Life Support Organization Maastricht Treaty for Nomenclature in Extracorporeal Life Support (Online Data Supplement)

A Position Paper of the Extracorporeal Life Support Organization

Steven A. Conrad, L. Mikael Broman, Fabio S. Taccone, Roberto Lorusso, Maximilian V. Malfertheiner, Federico Pappalardo, Matteo Di Nardo, Mirko Belliato, Lorenzo Grazioli, Ryan P. Barbaro, D. Michael McMullan, Vincent Pellegrino, Daniel Brodie, Melania M. Bembea, Eddy Fan, Malaika Mendonca, Rodrigo Diaz, Robert H. Bartlett

American Journal of Respiratory and Critical Care Medicine, 2018

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Table E1. Terminology for Systems and Support Modes

Term (Abbreviation)	Definition
Extracorporeal life support (ECLS)	A collective term for extracorporeal therapies used for the support of various presentations of cardiac and/or pulmonary failure through the use of an extracorporeal circuit (E1). *ECLS includes therapies focusing on oxygenation, carbon dioxide removal, cardiac support, or a combination thereof. It excludes cardiopulmonary bypass for cardiothoracic or vascular surgical procedures.*
Extracorporeal membrane oxygenation (ECMO)	ECMO is the provision of oxygen and carbon dioxide exchange through the use of an extracorporeal circuit consisting minimally of a blood pump, artificial lung, and vascular access cannulae, using blood flows sufficient to support oxygenation and concomitantly enhance carbon dioxide removal (E2, E3). *The term ECLS has been used interchangeably with the term ECMO, but ECMO is the preferred term when the goal is oxygen and carbon dioxide exchange by means of a pumped extracorporeal circuit.*
Venoarterial (VA) support	VA support is the application of extracorporeal circulation primarily for cardiac or circulatory support, in which the extracorporeal circuit drains blood from the venous system and returns into the systemic arterial system. Without qualification, VA support refers to support that returns blood to the systemic arterial system, operating in parallel with and providing partial or complete bypass of, the heart and lungs (E4, E5). Although used primarily for cardiac support, in selected circumstances VA support is used for respiratory or combined cardiac and respiratory support. *VA can be used to qualify the application of ECMO (VA ECMO).*
Venovenous (VV) support	VV support is the application of extracorporeal circulation primarily for respiratory support, in which the extracorporeal circuit drains blood from the venous system and reinfuses into the venous system. VV support operates in series with the heart and lungs, and does not provide bypass of these organs (E6, E7). *VV can be used to qualify the application of ECMO (VV ECMO). A variation of VV support is the use of a dual-lumen cannula inserted across the tricuspid valve into the pulmonary artery that provides support of right ventricular function in addition to gas exchange.*

Venovenoarterial (VVA) support	VVA is a hybrid configuration of VV and VA extracorporeal support in which the extracorporeal circuit drains blood from the venous system and reinfuses into both the venous and systemic arterial systems (E8, E9, E10). VVA ECMO provides both pulmonary (VV component) and cardiac support (VA component) in patients with combined cardiopulmonary failure. *VVA can be used to qualify the application of ECMO (VVA ECMO). The abbreviation VVA is preferred over VAV since it is a contraction of 'VV' and 'VA', and is established in the literature (E8).*
Extracorporeal cardiopulmonary resuscitation (ECPR)	ECPR is the application of rapid-deployment venoarterial extracorporeal membrane oxygenation, usually by peripheral cannulation, to provide circulatory support in patients in whom conventional cardiopulmonary resuscitation (CPR) is unsuccessful in achieving sustained return of spontaneous circulation (sustained ROSC) (E11, E12, E13). Sustained ROSC is deemed to have occurred when chest compressions are not required for 20 consecutive minutes and signs of circulation persist (E14). *ECPR implies the application of ECLS during conventional CPR. Use of ECLS initiated for low cardiac output following sustained ROSC is considered venoarterial (VA) ECMO.*
Extracorporeal carbon dioxide removal ($ECCO_2R$)	$ECCO_2R$ is the provision of carbon dioxide exchange through the use of an extracorporeal circuit consisting minimally of an optional blood pump artificial lung and vascular access cannulas using blood flows lower than required for oxygenation support (E15). *Peripheral cannulation for venovenous access using a blood pump would be the most common mode.*
Venovenous extracorporeal carbon dioxide removal (VV $ECCO_2R$)	VV $ECCO_2R$ is the provision of carbon dioxide exchange through the use of an extracorporeal circuit consisting of a blood pump, artificial lung, and venovenous vascular access cannulas using lower blood flows (E16).
Arteriovenous extracorporeal carbon dioxide removal (AV $ECCO_2R$)	AV $ECCO_2R$ is the provision of pumpless carbon dioxide exchange through the use of an extracorporeal circuit consisting of an artificial lung, and venous and arterial vascular access cannulas using lower blood flows. Blood flow is driven by the patient's arterio-venous pressure gradient (E17). Synonym: $AVCO_2R$, pECLA (pumpless extracorporeal lung assist), iLA (interventional lung assist)

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Cardiac ECMO (cECMO)	The use of extracorporeal membrane oxygenation with a primary indication for support of left and/or right ventricular failure by providing cardiac and gas exchange support. Does not imply any specific ECLS mode or cannulation configuration. Synonym: cECLS *cECMO is an abbreviation that can be used in a generic context when describing the type of organ support as cardiac.*
Respiratory ECMO (rECMO)	The use of extracorporeal membrane oxygenation with a primary indication for support of respiratory failure by providing gas exchange support. Does not imply any specific ECLS mode or cannulation configuration. Synonym: rECLS *rECMO is an abbreviation that can be used in a generic context when describing the type of organ support as respiratory.*
Extracorporeal interval support for organ retrieval (EISOR)	The use of venoarterial extracorporeal membrane oxygenation to provide organ perfusion in non-heart-beating organ donors in the interval between declaration of death and organ retrieval (E18). Synonym: Organ-preserving extracorporeal membrane oxygenation (OP-ECMO) (E19) *EISOR has been described in the context of death due to cessation of cardiorespiratory function, and OP-ECMO in the context of brain death, but both are intended to preserve organ function prior to retrieval.*
Prolonged ECLS	A continuous episode of extracorporeal support with duration more than 28 days. It does not indicate type or mode of ECLS. Synonym: Prolonged ECMO, when used in context of ECMO

Table E2. Terminology for Cannulation Concepts

Term	Definition
Vascular cannula	A plastic tube, inserted into the vascular system for drainage or reinfusion of blood, typically over a trocar or dilator and optionally using a guidewire. Vascular cannulas may have metal reinforcement to assist in preserving its shape and prevent kinking. Synonyms: Cannula (when the context of vascular cannula is understood) *Often used interchangeably, 'cannula' is preferred over 'catheter' since the latter does not typically involve a trocar or loading dilator, and the former is fully established in cardiovascular surgery and extracorporeal life support.*
Vascular cannulation	The procedure of insertion of a vascular cannula into a patient for purposes of extracorporeal circulation. Synonym: Cannulation *'Cannulation' is preferred over 'catheterization'*
Decannulation	The procedure of removal of a vascular cannula following termination of extracorporeal life support
Unplanned decannulation	The unintended or accidental partial or complete removal of a vascular cannula during extracorporeal life support prior to intended termination. Synonym: Accidental decannulation
Percutaneous cannulation	Minimally invasive placement of a cannula into a vessel through the skin aided by the use of a minimal skin incision, placement of a guidewire and sequential dilation of the insertion tract, based on the Seldinger technique (E20). *Percutaneous cannulation may be aided by the use of ultrasound and/or fluoroscopic imaging.*
Semi-percutaneous cannulation	A variation of percutaneous cannulation in which a surgical incision is made to expose the vessel, with placement of the guidewire and cannula through the skin using the Seldinger technique and guided into the vessel under direct visualization. Synonyms: Semi-open cannulation, semi-Seldinger cannulation

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Surgical cannulation	Placement of a cannula into a vessel under direct vision following incision of the skin, surgical exposure of the vessel(s), venotomy or/or arteriotomy, and placement of the cannula(s). Synonym: Open cannulation
Central cannulation	Direct cannulation of the cardiac chambers (e.g. right atrium) or central vessels (e.g. aorta) through a thoracic incision, usually a median sternotomy. *Central cannulation may include cannulation through an open or partially closed sternum, or through the use of tunneled cannula with a closed sternum.*
Peripheral cannulation	Cannulation of a vessel accessible by percutaneous or direct surgical access without entering the thoracic or abdominal cavities.
Single-lumen cannula	A cannula with a single internal lumen intended for placement in a major vein, the right atrium, or major artery. *A minimum of two single-lumen cannulas are required for extracorporeal support.*
Dual-lumen cannula	A cannula with two internal lumens intended for placement in a major vein, one or both vena cavae, the right atrium, and/or the pulmonary artery. Synonym: Double-lumen cannula. *Most dual-lumen cannulas are designed for venovenous support. The alternative application for dual-lumen cannulas is venoarterial for right ventricular support.*
Bi-caval cannula	A dual-lumen cannula designed for placement in, and drainage of, both the superior and inferior vena cavae. *Used in the context of dual-lumen cannulation for venovenous support, with reinfusion into the right atrium.*
Cavo-atrial cannula	A dual-lumen cannula designed for placement in, and drainage of, the superior vena cava and right atrium. *Used in the context of dual-lumen cannulation for venovenous support, with reinfusion into the right atrium*

Distal cannula	A secondary cannula placed distal to a primary cannula used for distal arterial perfusion or distal venous drainage of limb vessels where cannulation is performed. Synonym: Distal perfusion cannula (when used for arterial perfusion), or distal drainage cannula (when used for venous drainage) *A distal cannula is typically connected to the associated primary cannula.*

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Table E3. Terminology for Devices

Term (Abbreviation)	Definition
Blood pump	A mechanical device, typically powered by an electric drive motor, that produces blood flow by creating a hydrodynamic pressure gradient between an inlet and outlet port.
Centrifugal blood pump	An axisymmetric blood pump that produces a hydrodynamic pressure gradient through rotational kinetic energy through the use of an impeller assembly. The impeller is sealed within an operating chamber and magnetically coupled to the drive motor.
Roller blood pump	A peristaltic blood pump that produces a hydrodynamic pressure gradient through compression of a circular segment of tubing with a roller (wiper) that rotates and positively displaces the fluid in the tube.
Membrane lung	An extracorporeal gas exchange device for transfer of oxygen and carbon dioxide by diffusion across a membrane between a blood phase and a gas phase. Synonyms: Artificial lung, membrane oxygenator *The term membrane lung is preferred since it describes the fundamental gas exchange interface (membrane) and the analogy with the natural lungs for exchange of both oxygen and carbon dioxide.*
Hollow fiber membrane lung	A membrane lung in which the membrane is formed into capillaries, or hollow fibers. Modern hollow fiber membrane lungs use extracapillary blood flow, in which blood flows in the region exterior to the fibers and gas flows in the region interior to the fibers.
Sweep gas	The gas applied to the gas phase of the membrane lung. *Oxygen, air, or air blended with oxygen are used for the sweep gas. In specialized circumstances, other gases such as carbon dioxide, volatile anesthetics or nitric oxide may be added.*
Sweep gas flow	The volumetric flow rate of sweep gas applied to the membrane lung. Synonym: Sweep flow *The volumetric sweep gas flow is controlled by an external flowmeter.*

Sweep gas:blood flow ratio (Q_G/Q_B)	The ratio of sweep gas flow to blood flow in a membrane lung, usually expressed relative to unit blood flow. *A sweep gas:blood flow ratio of 1:1 indicates a volumetric sweep gas flow equal to the volumetric blood flow.*
Sweep gas inlet oxygen fraction (F_SO_2)	The oxygen fraction of the sweep gas supplied to the membrane lung, usually ranging from 0.21 to 1.0. The fraction is controlled by a *gas blender*. Synonyms: F_DO_2 (device inlet oxygen fraction) *The abbreviation is intended to distinguish it from F_IO_2, which is the inspired oxygen fraction provided to the patient through the airway.*
Device inlet carbon dioxide fraction (F_SCO_2)	The carbon dioxide fraction of the sweep gas supplied to the membrane lung, usually ranging from 0.01 to 0.05. The fraction is controlled by a rotameter or gas blender. Synonyms: F_DCO_2 (device inlet carbon dioxide fraction) *Carbon dioxide may be mixed into the sweep gas in a physiologic concentration to manage respiratory alkalosis not amenable to sweep gas flow reduction, or as a means to assess the native lung's capacity for carbon dioxide clearance.*
Heat exchanger	A device which transfers heat between a recirculating water phase and the blood phase of the ECLS circuit, separated by a heat exchanging material, usually metal or plastic. *Modern artificial membrane lungs have heat exchangers integrated into their design.*
Heater-cooler unit	A device which provides recirculating water at a controlled specified temperature to the heat exchanger.
Bridge	A segment of circuit tubing component inserted between the drainage and reinfusion limbs near the cannulation connections, acting as a shunt for recirculating circuit blood when the cannulas are clamped or disconnected. It is commonly used to facilitate weaning from VA ECLS (E21). *The term 'bridge' is historically well established and appears unique to extracorporeal life support.*

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Loop	A segment of narrow-diameter tubing inserted between the reinfusion and drainage limbs close to the inlet side of the pump and the outflow side of the membrane lung, acting as a low-flow shunt with the purpose of monitoring, blood sampling and administration of pharmaceuticals. The loop is continuously open for low-flow oxygenator-to-pump recirculation. *The loop allows for outlet blood gases assessments without risk for emboli being injected into the circuit after the membrane lung.*
Bladder	An optional venous reservoir in an ECLS circuit characterized by 1) small size, 2) completely enclosed design and 3) absence of air-blood interface. *The term 'bladder' is historically well established and appears unique to extracorporeal life support.*
Arterial filter	A filter placed in the blood phase, typically as the last component in the circuit, that can capture particulates such as micro blood and gas emboli and prevent their infusion into the patient.
Surface modification	The application of compounds to the blood-contacting surfaces of an extracorporeal circuit or circuit component for purposes of improving biocompatibility during extracorporeal support. Synonym: Surface coating, coated circuit

Table E4. Terminology for Circuit Operation

Term (Abbreviation)	Definition
Circuit prime	The physiologic solution introduced into the ECLS circuit prior to initiating support, displacing all air in the circuit.
Crystalloid prime	A circuit prime consisting of isotonic, usually balanced electrolyte, crystalloid solutions, optionally with additional electrolytes such as calcium. It is free of albumin or banked blood products. Synonym: Clear prime
Albumin prime	A crystalloid circuit prime with added albumin. It is free of banked blood products. Synonym: Colloid prime
Blood prime	A crystalloid or albumin circuit prime with added banked red blood cells, optionally with plasma.
Drainage	Drainage is the process of removal of blood from the vascular system for purposes of extracorporeal circulation. The cannula(s) used to effect drainage are referred to as *drainage cannulas*. *The term drainage is preferred over alternative terms such as 'venous limb' or 'venous cannula' since drainage may occur from cannulation of either a vein or an artery.*
Gravity drainage	The use of a hydrostatic column of blood in the venous drainage limb to assist venous drainage. It is achieved by elevating the patient relative to the level of the blood pump. *Gravity drainage produces a positive pressure at the pump inlet relative to ambient pressure. It can be used with any blood pump technology, but is the only drainage assist that can be used with roller blood pumps.*
Kinetic drainage	The use of a pump-generated controlled suction on the venous drainage limb of the circuit to assist venous drainage. *At present this is only a capability of centrifugal blood pumps, and is achieved and controlled through the rotational speed of the blood pump.*

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Return	Return is the process of returning blood from the extracorporeal circuit to the vascular system for purposes of extracorporeal circulation. The cannula(s) used to effect blood return are referred to as *return or reinfusion cannulas*. Synonym: Reinfusion *The term return is preferred over alternative terms such as 'arterial limb' or 'arterial cannula' since return may occur using cannulation of either an artery or a vein.*
Recirculation	Recirculation is the phenomenon observed during venovenous ECLS in which a portion of the reinfused blood from the circuit is returned to the circuit through the drainage cannula instead of flowing to the patient (E22, E23). *Recirculation is limited to venovenous (or venovenoarterial) cannulation only, since the other modes reinfuse into a separate portion of the circulation.*
Recirculation fraction (R*f*)	The fraction of total extracorporeal flow (Q_{EC}, as measured by reinfusion flow to the patient) that is recirculated (Q_{REC}, flowing directly from the reinfusion cannula into the drainage cannula), calculated as $Rf = Q_{REC}/Q_{EC}$ (E24).
Effective extracorporeal flow (Q_{EFF})	The fraction of total extracorporeal blood flow that contributes to oxygen delivery to the patient, calculated as $Q_{EFF} = Q_{EC}(1\text{-}Rf)$, representing the recirculation flow subtracted from total extracorporeal flow.
Extracorporeal flow fraction (EFF)	The fraction of total systemic blood flow captured by the extracorporeal circuit.
Cavitation	The occurrence of vapor cavities or voids in the blood phase that result from a rapid decrease in fluid pressure. In the ECLS circuit these voids can occur where negative pressures develop, such as near or at the blood pump inlet, and are usually transient (inertial cavitation).
Rated flow	An industry-standard rating of membrane lung oxygen transfer performance. It is defined as the blood flow at which a specified inlet blood saturation (typically 75%) is raised to a specified outlet blood saturation (typically) 95% under conditions of a specified hemoglobin (typically) 12 g/dl, a sweep gas:blood flow ratio of 1:1 (E25, E26).
Inlet saturation ($S_{PRE}O_2$)	The oxygen saturation of hemoglobin measured at the inlet of the membrane lung. Synonym: drainage saturation, pre-membrane lung saturation, pre-oxygenator saturation

Outlet saturation ($S_{POST}O_2$)	The oxygen saturation of hemoglobin measured at the outlet of the membrane lung. Synonym: post-membrane lung saturation, post-oxygenator saturation
Pump inlet pressure (P_{INLET})	The fluid pressure in the blood phase before the roller or centrifugal pump. Synonym: Pre-pump pressure
Pre-membrane pressure (P_{PRE})	The fluid pressure in the blood phase at the inlet to the membrane lung.
Post-membrane pressure (P_{POST})	The fluid pressure in the blood phase at the outlet of the membrane lung.
Membrane pressure drop (ΔP)	The pressure gradient between the inlet and outlet of the membrane lung, calculated as the difference between the post-membrane and pre-membrane pressures (P_{PRE} - P_{POST}). Synonym: Delta P *The term transmembrane pressure has been used in this context, but this technically refers the pressure gradient across the diffusion membrane itself between the gas and blood phases.*
Differential hypoxemia	A pattern of hypoxemia in which arterial saturation differs between circulatory beds and is low in at least one of the regions, usually between the lower body and all or part of the upper body (E27, E28). Synonyms: Regional hypoxemia, Dual-circuit circulation on VA ECMO, North-South phenomena, Harlequin phenomena *This pattern of hypoxemia is exclusively associated with VA ECMO via peripheral, and in particular femoral, cannulation.*
Global hypoxemia	A pattern of hypoxemia in which arterial saturation is low and consistent throughout the arterial circulation. Synonym: Systemic hypoxemia *This pattern of hypoxemia is usually associated with VV ECMO.*

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Left ventricular venting	Drainage of blood flow from the left heart during ECLS through a route other than the primary drainage cannula. Venting techniques include left atrial venting catheter placement, atrial septostomy, pulmonary valve stenting, pulmonary artery drainage catheter placement, and left ventricular apical drainage. Venting procedures drain blood into the circuit or right heart, but do not return blood to the aorta.
Left ventricular unloading	A procedure intended to mechanically assist ventricular ejection into the aorta during ECLS. Unloading procedures include intra-aortic balloon counterpulsation and trans-aortic axial pump support.
ECLS initiation	Initiation of extracorporeal circuit flow to the patient following cannulation and circuit connection to cannulas.
ECLS implantation	The procedure encompassing both cannulation and initiation of extracorporeal circuit flow.
Weaning trial	The procedure of a reduction in circuit blood flow and/or sweep gas flow with assessment of patient response with the intention of discontinuation of ECLS.
Discontinuation trial	The procedure of temporarily removing a patient from extracorporeal support for the purpose of assessing continued need for support. Synonym: Trial off *The discontinuation trial procedures will vary depending on the type of support, type of blood pump, and presence or absence of a bridge.*
Pump-controlled retrograde discontinuation trial	A discontinuation trial during VA support in which the centrifugal blood pump speed is reduced to allow a small, controlled amount of retrograde blood flow (E29). *This type of discontinuation trial requires a non-occlusive (centrifugal) blood pump.*
ECLS discontinuation	Removal of extracorporeal circuit flow to the patient with circuit disconnection from cannulas
ECLS explantation	The procedure encompassing both discontinuation of extracorporeal support and decannulation.

Table E5. Units of Measurement

Physical concept	Unit	Definition
Pressure	Millimeters of mercury (mmHg)	Preferred unit of pressure for ECLS, applied to absolute fluid pressures within the ECLS circuit and to partial pressures of gases in blood.
Volumetric flow	Liters per minute (L/min)	Preferred unit of volumetric flow for ECLS, applied to both blood flow and sweep gas flow.
Length	Centimeter (cm)	Preferred unit for cannula length, cannula insertion depth, and device dimension measurements.
	Meter (m)	Preferred unit for circuit tubing length and other lengths that exceed approximately 50 cm
	Inch (in)	Preferred unit for circuit tubing diameter.
	French (Fr)	Preferred unit for cannula diameter.
Area	Square meter (m^2)	Preferred unit for surface area, such as artificial membrane lung surface area.
Temperature	Degrees Centigrade (C°)	Preferred unit for temperature, including body temperature, blood temperature, and circuit component temperatures.

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

Table E6. Abbreviations for Peripheral Cannulation

Level	Abbreviation	Definition
Primary or secondary access	A or a	Systemic artery
	V	Systemic vein
	P	Pulmonary artery
Cannulation site	c	Carotid artery
	f	Femoral vessel
	j	Jugular vein
	s	Subclavian vessel
Central cannulation sites	RA	Right atrium
	LA	Left atrium
	LV	Left ventricle
	AO	Aorta
	PA	Pulmonary artery
	v_a	Left atrial vent

References

E1. Bartlett RH, Conrad SA. The physiology of extracorporeal life support. In: Brogan TV, Lequier L, Lorusso R, MacLaren G, Peek G, editors. Extracorporeal Life Support: The ELSO Red Book, 5 ed. Ann Arbor, MI: Extracorporeal Life Support Organization; 2017.

E2. Abrams D, Combes A, Brodie D. Extracorporeal membrane oxygenation in cardiopulmonary disease in adults. *J Am Coll Cardiol* 2014; 63: 2769-2778.

E3. Frenckner B. Extracorporeal membrane oxygenation: a breakthrough for respiratory failure. *J Intern Med* 2015; 278: 586-598.

E4. Gille JP, Bagniewski AM. Ten years of use of extracorporeal membrane oxygenation (ECMO) in the treatment of acute respiratory insufficiency (ARI). *Trans Am Soc Artif Intern Organs* 1976; 22: 102-109.

E5. Zapol WM, Snider MT, Schneider RC. Extracorporeal membrane oxygenation for acute respiratory failure. *Anesthesiology* 1977; 46: 272-285.

E6. Andrews AF, Toomasian J, Oram A, Bartlett RH. Total respiratory support with venovenous (VV) ECMO. *Trans Am Soc Artif Intern Organs* 1982; 28: 350-353.

E7. Andrews AF, Klein MD, Toomasian JM, Roloff DW, Bartlett RH. Venovenous extracorporeal membrane oxygenation in neonates with respiratory failure. *J Pediatr Surg* 1983; 18: 339-346.

E8. Stöhr F, Emmert MY, Lachat ML, Stocker R, Maggiorini M, Falk V, Wilhelm MJ. Extracorporeal membrane oxygenation for acute respiratory distress syndrome: is the configuration mode an important predictor for the outcome? *Interact Cardiovasc Thorac Surg* 2011; 12: 676-680.

E9. Biscotti M, Lee A, Basner RC, Agerstrand C, Abrams D, Brodie D, Bacchetta M. Hybrid configurations via percutaneous access for extracorporeal membrane oxygenation: a single-center experience. *ASAIO J* 2014; 60: 635-642.

E10. Werner NL, Coughlin M, Cooley E, Haft JW, Hirschl RB, Bartlett RH, Mychaliska GB. The University of Michigan experience with veno-venoarterial hybrid mode of extracorporeal membrane oxygenation. *ASAIO J* 2016; 62: 578-583.

E11. Bělohlávek J, Chen Y-H, Morimura N. Extracorporeal cardiopulmonary resuscitation in adults. In: Brogan TV, Lequier L, Lorusso R, MacLaren G, Peek G, editors. Extracorporeal Life Support: The ELSO Red Book, 5 ed. Ann Arbor, MI: Extracorporeal Life Support Organization; 2017.

E12. Conrad SA, Rycus PT. Extracorporeal membrane oxygenation for refractory cardiac arrest. *Ann Card Anaesth* 2017; 20: S4-S10.

E13. Yam N, McMullan DM. Extracorporeal cardiopulmonary resuscitation. *Ann Transl Med* 2017; 5: 72.

E14. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, Cassan P, Coovadia A, D'Este K, Finn J, Halperin H, Handley A, Herlitz J, Hickey R, Idris A, Kloeck W, Larkin GL, Mancini ME, Mason P, Mears G, Monsieurs K, Montgomery W, Morley P, Nichol G, Nolan J, Okada K, Perlman J, Shuster M, Steen PA, Sterz F, Tibballs J, Timerman S, Truitt T, Zideman D, International Liaison Committee on R, American Heart A, European Resuscitation C, Australian Resuscitation C, New Zealand Resuscitation C, Heart, Stroke Foundation of C, InterAmerican Heart F, Resuscitation Councils of Southern A, Arrest ITFoC, Cardiopulmonary Resuscitation O. Cardiac arrest and cardiopulmonary

AJRCCM Articles in Press. Published on 03-April-2018 as 10.1164/rccm.201710-2130CP

resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation* 2004; 110: 3385-3397.

E15. Gattinoni L, Kolobow T, Damia G, Agostoni A, Pesenti A. Extracorporeal carbon dioxide removal (ECCO2R): a new form of respiratory assistance. *Int J Artif Organs* 1979; 2: 183-185.

E16. Gattinoni L, Kolobow T, Agostoni A, Damia G, Pelizzola A, Rossi GP, Langer M, Solca M, Citterio R, Pesenti A, Fox U, Uziel L. Clinical application of low frequency positive pressure ventilation with extracorporeal CO2 removal (LFPPV-ECCO2R) in treatment of adult respiratory distress syndrome (ARDS). *Int J Artif Organs* 1979; 2: 282-283.

E17. Conrad SA, Zwischenberger JB, Grier LR, Alpard SK, Bidani A. Total extracorporeal arteriovenous carbon dioxide removal in acute respiratory failure: a phase I clinical study. *Intensive Care Med* 2001; 27: 1340-1351.

E18. Dejohn C, Zwischenberger JB. Ethical implications of extracorporeal interval support for organ retrieval (EISOR). *ASAIO J* 2006; 52: 119-122.

E19. Dalle Ave AL, Gardiner D, Shaw DM. The ethics of extracorporeal membrane oxygenation in brain-dead potential organ donors. *Transpl Int* 2016; 29: 612-618.

E20. Seldinger SI. Catheter replacement of the needle in percutaneous arteriography; a new technique. *Acta Radiol* 1953; 39: 368-376.

E21. Babar ZU, Sharma AS, Ganushchak YM, Delnoij TS, Donker DW, Maessen JG, Weerwind PW. An arterio-venous bridge for gradual weaning from adult veno-arterial extracorporeal life support. *Perfusion* 2015; 30: 683-688.

E22. Abrams D, Bacchetta M, Brodie D. Recirculation in venovenous extracorporeal membrane oxygenation. *ASAIO J* 2015; 61: 115-121.

E23. Broman M, Frenckner B, Bjallmark A, Broome M. Recirculation during veno-venous extra-corporeal membrane oxygenation--a simulation study. *Int J Artif Organs* 2015; 38: 23-30.

E24. Palmer O, Palmer K, Hultman J, Broman M. Cannula design and recirculation during venovenous extracorporeal membrane oxygenation. *ASAIO J* 2016; 62: 737-742.

E25. Holdefer WF, Tracy WG. The use of rated blood flow to describe the oxygenating capability of membrane lungs. *Ann Thorac Surg* 1973; 15: 156-162.

E26. Lequier L, Horton SB, McMullan DM, Bartlett RH. Extracorporeal membrane oxygenation circuitry. *Pediatr Crit Care Med* 2013; 14: S7-12.

E27. Kitamura M, Shibuya M, Kurihara H, Akimoto T, Endo M, Koyanagi H. Effective cross-circulation technique of venoarterial bypass for differential hypoxia condition. *Artif Organs* 1997; 21: 786-788.

E28. Hou X, Yang X, Du Z, Xing J, Li H, Jiang C, Wang J, Xing Z, Li S, Li X, Yang F, Wang H, Zeng H. Superior vena cava drainage improves upper body oxygenation during veno-arterial extracorporeal membrane oxygenation in sheep. *Crit Care* 2015; 19: 68.

E29. Westrope C, Harvey C, Robinson S, Speggiorin S, Faulkner G, Peek GJ. Pump controlled retrograde trial off from VA-ECMO. *ASAIO J* 2013; 59: 517-519.