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Editors

Extracorporeal life support

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Preface

Extracorporeal life support (ECLS), which is previously named as "extracorporeal membrane oxygenation" (ECMO) by many practitioners, has emerged to describe the entire family of extracorporeal support modalities for long-term support and has been popularized widely and applied in various fields since the twenty-first century. The ECLS member units reported by Extracorporeal Life Support Organization (ELSO) Annual Reports have also increased year by year. In particular, the outbreak of SARS and COVID-19 has praised ECLS as a "magic tool" to control the epidemic. However, the clinical outcomes of patients using ECLS have not improved substantially in the past few decades. This has a lot to do with the type of basic primary diseases of patients, but it is also directly related to the timing of assistance, the selection of ECLS methods, the screening of implantation sites, the reasonable management during ECLS, prevention of various complications, and the timely removal of ECLS.

In the past, most practitioners engaged in ECLS refer to The ELSO red book for management of ECLS. Many pilots of ECLS have propagated and promoted the professional development of ECLS with establishment and update of the ELSO database, compilation of ELSO red book, introduction of recommendations or guidelines. However, the emergence of new ECLS consumables, especially the emergence of new ECLS indications and the adapted population, requires professionals to reassess ECLS. Many clinical problems still need specific practitioners to report and communicate information with them, rather than covering up some iatrogenic errors and decision-making bias. With the continuous progress of other medical specialties, many patients and their relatives have higher requirements and expectations for such patients, urging us to re-examine the protocol of treatment, therapeutic strategies, and treatment concept of such critically ill patients. The development of multidisciplinary consultations helps to optimize the adjustment of treatment during ECLS. Therefore, we have organized domestic and some foreign experts to update the relevant content of this field. We hope that the publication of this work can provide the basic theoretical model of ECLS for front-line practitioners, and certain reference for the treatment of critically ill patients.

Although all our three chief editors are from China and English is not our native language, the current world is a diversified world, and the geographical boundaries cannot block the communication and cooperation of such professionals. We hope that this work can become a form of academic exchange in ECLS.

Beijing, China — Feilong Hei
Beijing, China — Yulong Guan
Beijing, China — Kun Yu

Introduction of Chief Editor, Feilong Hei

The Main Academic Title

The Chairman of Continuing Education Committee of Chinese Biomedical Engineering Association; the Former Chairman of Chinese Society of Extracorporeal Circulation; the Chairman of Beijing Society of Extracorporeal Circulation; the Vice Chairman of Extracorporeal Life Support Professional Committee of Chinese Medical Doctor Association; the Vice Chairman of Extracorporeal Life Support and Circulation Committee of Chinese Research Hospitals Association; the Director of Beijing Society of Medical Education; the Editor in Chief of Chinese Journal of Extracorporeal Circulation.

Scientific Research and Clinical Achievements

He is proficient in extracorporeal life support and cardiopulmonary bypass during cardiac surgery and heart transplantation. His research interests include "Myocardial Protection", "Extracorporeal Membrane Oxygenation" and "Tissue Engineering—Artificial Lung". Totally, he has published 34 SCI papers and 186 articles in Chinese; edited and participated in 17 monographs; invented 3 patents; presided 7 research projects, including four projects of the National Natural Science Foundation of China; participated in four projects, including two National Key Research and Development Programs of China and one Project in the National Science and Technology Pillar Program during the Eleventh Five-Year Plan period.

Introduction of Chief Editor, Yulong Guan

The Main Academic Title

Member of National Natural Science Foundation of China and Beijing Natural Science Foundation Expert Database; Member of National Expert Database of Science and Technology, Ministry of Science and Technology; Invited foreign reviewer for "Artif Organs", "Journal of Clinical Case Studies", "Journal of Pediatric Intensive Care"; member of Editorial Board, Journal of Cardiovascular and Pulmonary Disease; Standing member of the third Committee, Blood Management Branch of Chinese Society of Cardiothoracic Anesthesia; member of Editorial Board, Biomedical Engineering and Clinical Medicine; Invited reviewer, Chinese Journal of Trauma; Member of Cardiac Function Committee of Chinese Medical Information Society.

Scientific Research and Clinical Achievements

For years engaged in the basic and clinical scientific research on central nervous system protection during the cardiovascular surgery, participated in and presided over a series of scientific research projects including:

- National natural science fund funding project (81170233; 30371412, 39770733)
- CAMS Innovation Fund for Medical Sciences (2020-I2M-C&T-B-066)
- Independent project of National Clinical Research Center, Fuwai Hospital, Chinese Academy of Medical Sciences, and Peking Union Medical College (NCRC2020005)
- Research Foundation of the Ministry of Education for returned overseas students (2013-LH01)
- Beijing Science and Technology Plan (2011-BKJ04)
- Union Youth Research Fund (2011-xh1)
- University doctoral Foundation of Ministry of Education (2010-GB01, 200800231118, 2006-GB04)
- Youth Foundation, Fuwai Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College (2008F004)
- Beijing Science and Technology New Star project (951871000)

Scientific Achievements

- Young Investigator Award, Seventh international Conference on Pediatric Mechanical Circulatory Support Systems and Pediatric Cardiopulmonary Bypass, Philadelphia, USA, 2011
- Second Prize of Beijing Science and Technology Progress Award (H01-2004-069)

Scientific Training

As a post-doctoral fellow, received Specialist Training on extracorporeal life support and simulated training of pediatrics and extracorporeal circulation in Hershey Medical Center, Hershey, Pennsylvania, USA, from Oct 25th, 2008 to Nov 1st, 2009.

Scientific Monographs

Participated in the compilation of more than 10 domestic monographs on extracorporeal circulation and extracorporeal life support.

Scientific Papers

Up to now, more than 90 papers have been published including 15 SCI papers as the first author or corresponding author.

Introduction of Chief Editor, Kun Yu

The Main Academic Title

Chief physician of Extracorporeal Circulation Center of Fuwai Hospital, Master tutor. Secretary General of Extracorporeal Life Support Branch of Chinese Society of Cardiothoracic and Vascular Anesthesia; Evaluation expert of Chinese Medical Doctor Association standardized training of resident physicians in the direction of cardiothoracic surgery; Member of Chinese Extracorporeal Circulation Society; Member of the Professional Committee of Extracorporeal Life Support and Society of Chinese Research Hospital Society, Member of Extracorporeal Life Support Branch of Chinese Medical Rescue Association.

Scientific Research and Clinical Achievements

She has presided over and participated in a number of national and provincial scientific research projects, published more than 50 papers. She is the editor-in-chief of professional book *Modern Cardiopulmonary Bypass*, and the deputy chief editor of professional books *Manual of Extracorporeal Circulation*, and *Manual of ECMO*. Additionally, she is the principal translator of the Braunwald's cardiology companion book *Mechanical Circulatory Support*.

She is proficient in cardiopulmonary bypass techniques for complicated cases as well as extracorporeal life support (previously named as ECMO). She has participated in the quality control of cardiopulmonary bypass techniques in China and performed more than 3000 cases of CPB and 100 cases of ECMO.

Contents

Physiology of Extracorporeal Life Support

1

Shigang Wang

The primary function of the heart and lungs is the provision of blood circulation, to provide oxygen (**O_2**) and other nutrients to the cells and to remove the products of metabolism including carbon dioxide (**CO_2**). During open heart surgery, cardiopulmonary bypass (**CPB**) may be used to isolate the heart and lungs and replace whole functions of the heart and lungs during aortic cross-clamp and provide quiet, bloodless field for the performance of surgery. The utilization of CPB involves the use of an oxygenator with a cardiotomy/venous reservoir, roller or centrifugal pumps, filters, tubing, and cardiotomy suction devices. Unlike CPB, extracorporeal life support (**ECLS)** is one modified CPB technology used in patients with life-threatening heart and/or lung failure, including veno-arterial (**VA**), venovenous (**VV**), and venovenoarterial (**VVA**) extracorporeal membrane oxygenation (**ECMO**) and VV and arteriovenous (**AV**) extracorporeal carbon dioxide removal (**$ECCO_2R$**) [1]. The ECMO system partially takes the functions of the heart and lungs for prolonged cardiopulmonary support, allowing the heart and lungs to rest, stopping damaging heart and lung treatment, and recovering functions of the failing organs (***bridge-to-recovery***) or as a bridge to long-term ventricular assist (***bridge-to-VAD***), heart or lung transplantation (***bridge-to-transplantation***), or destination therapy (***bridge-to-destination***) for suitable candidates with irreversible disease (Fig. 1.1) [2].

Different ECMO types and strategies have strongly different effects on circulatory and respiratory support. To manage patients on ECMO, it is essential to thoroughly understand the cardiopulmonary physiology, pathophysiology, and ECMO physiology.

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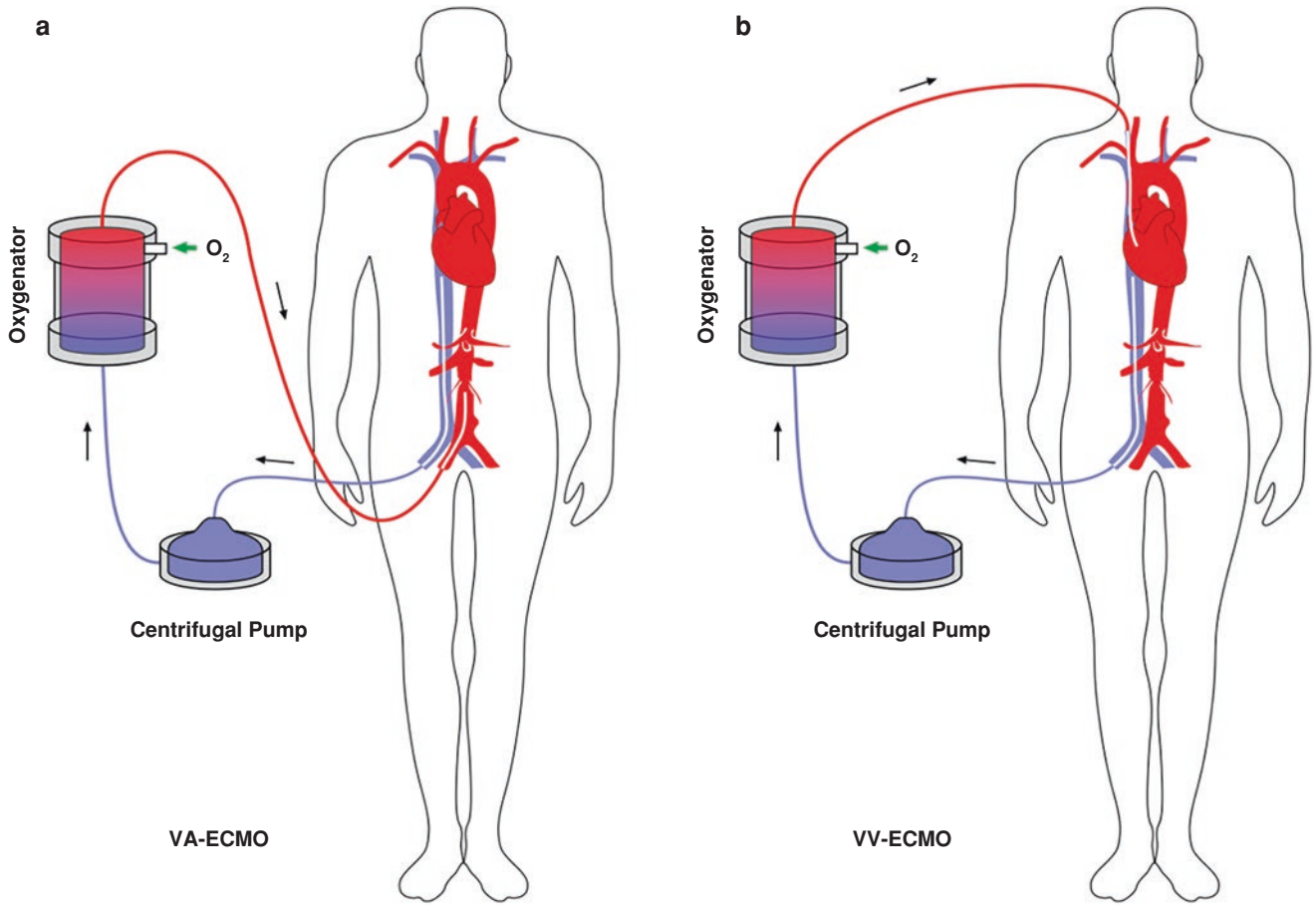

Fig. 1.1 The two main types of ECMO configuration. (**a**) venoarterial (VA) ECMO, (**b**) venovenous (VV) ECMO

Cardiovascular Physiology

The cardiovascular system consists of the heart (as a pump), blood vessels (a closed tube), and the blood (carries and transports materials to and from all parts of the body). The heart drives blood through the lungs for pulmonary gas exchange (pulmonary circulation) and through a closed blood vessel system (including arteries, arterioles, capillaries, venules, and veins) for the exchange of materials (systemic circulation). The lungs receive all blood to perform gas exchange in the pulmonary microcirculation. They are only organs that communicate with the external environment in the cardiovascular system, where O_2 and CO_2 are exchanged. Most systemic organs are arranged in parallel with the cardiovascular system. They receive identical blood and different flow independently controlled by the body. Many of the systemic organs serve to recondition the composition of blood, such as the kidneys, abdominal organs, and skin. They can temporarily withstand severe reduction of blood flow, because their normal blood flow is much more than that necessary to maintain their basal metabolic needs. However, the brain and myocardium cannot tolerate blood flow interruptions, because normal blood flow to the brain and myocardium is just slightly greater than that required for their metabolic needs. Therefore, unconsciousness will occur within a few seconds after any cease in cerebral blood supply, permanent brain damage will occur after only 4 min without oxygen, and brain death may occur as soon as 4–6 min later. The heart will reduce its pumping ability within beats of a coronary flow interruption, because the heart muscle consumes approximately 75% of the oxygen in supplied blood which only supplies the metabolic need of the heart [3].

Heart

The heart is a muscular organ that is filled with blood (preload) from the venous side, rhythmically contracts (contractility), and ejects blood against pressure (afterload) to the arterial side. The heart generates a unidirectional blood flow with the help of the orderly contraction sequence of the different heart chambers and the presence of cardiac valves.