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Chapter

Introductory Chapter: ECMO – Rapidly Evolving Technology, Expanding Indications, and Growing Challenges

Michael S. Firstenberg and Jennifer M. Hanna

1. Introduction

This text is now the third volume in a series of books focused on extracorporeal membrane oxygenation (ECMO) and extracorporeal life support (ECLS) [1]. With each volume, it becomes clearer that there has been a rapid evolution in the technology and the applications of it with regard to indications, management, outcomes, and the challenges in offering a very resource-intensive (and expensive) therapy in which the overall benefits are still questioned. Nevertheless, without a doubt, there has been an ongoing evolution of the use of ECMO as a salvage therapy offered only in extreme and potentially inherently futile cases, to now a mainstream therapy that can be routinely offered in well-defined cases of acute cardiac and respiratory failure. Early experiences resulted in few survivors and poor outcomes, but the reasons for this were clearly complex and multifactorial etiologies [2]. The development of more advanced pumps and circuits, better resources and guidelines for patient selection and management, and a broader understanding of the complex interactions between humans and an extracorporeal pump circuit for longer periods of time all have contributed to the advances in ECMO as an appropriate and reasonable therapy—even, as some would debate, standard of care for acute respiratory failure and/or cardiogenic shock. As these three volumes illustrate, over the years, there has been tireless improvements in all aspects of the use of ECMO. However, as the chapters in this text clearly illustrate, there is still much to be learned and understood. Challenges remain as clinicians continue to push the envelope of this technology to better define a patient population that might benefit from ECMO and how to apply and manage a very complex therapy to optimize outcomes [3].

As the indications for therapy evolve, there continues to be unusual and challenging clinical situations that deserve special attention for many reasons. For example, the chapter by Professor Nandini highlights the very complex issue that is becoming more common—the role of ECMO as a bridge to transplant. It was only a few years ago (and illustrated in the previous texts in this series) that the concept of ECMO as bridge to transplant was discouraged and difficult to justify due to the risks, concerns of limited resource allocation, and technical difficulties to a concept and management pathway that is routinely considered and offered to selected patients.

Additional chapters focus on the growing literature and experiences in other specific disease state or clinical situations for which ECMO might be considered.

One area that is particularly challenging is incorporating ECMO into the management of patients who develop acute cardiopulmonary collapse. ECMO-assisted CPR (eCPR) is one of the fastest growing uses of ECMO, and many rapid response/code teams are increasingly using ECMO in the management of patients who develop cardiac arrest. The data, experiences, and outcomes in this very complex area are rapidly evolving, and the controversies are substantial. The chapter by Dr. Lakshmi illustrates the current state of the art in this area and how patients can be selected and managed, with a focus on illustrating the improved outcomes in a patient population that was historically considered unsalvageable. Other similar unique applications for ECMO discussed in this text include a chapter on carbon dioxide removal by Dr. Morales-Quinteros. The very unusual role of normothermic regional perfusion in the setting of solid organ transplantation is discussed by Dr. Constantino.

A major focus of this volume is the specific management challenges that complicate the use of ECMO, especially in high-risk patient populations. Despite a greater awareness, peripheral cannulation techniques that are often used are associated with high rates of limb complications including amputation. Such concerns are discussed in the chapter by Dr. Prashant. Imaging of patients on ECMO, with an emphasis on assessing for cardiac recovery and prognosis, is especially important and discussed by Dr. Luigi, while the actual techniques, concepts, and applications of various weaning strategies are the focus of another chapter. Meanwhile, Dr. Weller's chapter on anticoagulation in the pediatric patient and Dr. Pinto's chapter on neurologic complications and monitoring revisit some of the difficult topics addressed in the previous editions and emphasize the growing experiences and literature in these complex topics [4, 5]. As some aspects of these topics have been addressed in the earlier books in this series, the contemporary experiences highlight that there remains much to understand and learn about many of these topics.

Again, it is also clear that to successfully offer ECMO as a viable therapy—and especially to strive for reasonable outcomes—there must be alignment of all key stakeholders. Without a doubt, ECMO requires an extensive team of providers at all levels working together in a manner that respects professionalism, competencies, compassion, and strict attention to details. The substantial and tireless efforts of the entire team must be recognized and appreciated by all and at all levels [6].

A frequently asked question is "how do we start an ECMO program?" Offering ECMO as a therapy involves so much more than just purchasing capital equipment and some disposable supplies. The chapter on program development emphasizes the many administrative aspects that must be considered within an appropriate framework to establish a program. This chapter considers the importance of physician, nursing, and administrative leadership and collaboration as a foundation for a successful program. While a great deal has been written on the extensive medical and surgical aspects of the management of a patient on ECMO, the chapter by Mr. Botsch and colleagues reviews the many aspects of the nursing bedside care. Of course, these topics continue to illustrate the importance of teamwork which cannot be overemphasized.

As discussed in the previous editions, a highly functioning "ECMO team" is a cornerstone in building a successful program. The ability to initiate therapy at any time and place is increasingly considered an important component of a well-organized team. While the makeup of an ECMO team can vary across institutions; each requires a champion to provide leadership and help with structure and organization. A fundamental principle is effective communication and a multidisciplinary approach to all aspects of management. Just as importantly, all

members of the team—regardless of experiences, education, training, degrees, and titles—need to have respect and trust and place value on all aspects of the contributions of all members. This is the basis of crew resource management (CRM). The key concept of CRM is that every team member has input and that each voice is valued and respected. Every member of the team needs to be empowered to speak up, particularly when there are concerns about safety. The different disciplines that are represented in an ECMO Team, as mentioned, can vary from program to program, but given the complexities of patient selection and management—including, the least of which are the technical aspects of cannulation and cannula management—membership must be comprehensive with regard to surgical and medical expertise. Membership should include, but clearly, not be limited to:

Physicians

- Surgeons (cardiothoracic, general, trauma, emergency medicine)
- Critical care intensivists (pulmonary, surgical)
- Medical specialists (infectious disease, neurology, cardiology, nephrology)

Advanced providers

- Nursing (bedside, advanced practice providers)
- Pharmacists
- Perfusionists
- Respiratory therapists
- Social workers/case management

Palliative care

- Often physician or advance practice nurses

Hospital leadership and administration

- C-suite executives (chief executive, financial, operating, and other officers)
- Quality managers
- Marketing

It is critical that even with dedicated, hardworking, and engaged clinical teams, there must be support and encouragement from hospital leadership and administration (**Figure 1**) [7].

Many of the chapters in these volumes discuss the various indications for ECMO (veno-venous and venoarterial) support and special patient populations and circumstances. However, a critical component of any program remains the role of striving for optimal clinical outcomes. Regardless of the indications and populations, outcomes and clinical complications (e.g., renal failure, limb complications,

Figure 1.
ECMO "team". Adopted from reference intro chapter in Volume 1 [1].

transfusion rates, etc.) must be tracked and compared to published benchmarks. Quality conferences in which cases are discussed can help a team and program formally recognize their successes while looking for opportunities for collective improvement. As discussed previously in the introductions (and various chapters) of the previous volumes, outcomes still remain less than ideal with survival rates that range from 60 to 70% for veno-venous respiratory support and 25–35% for venoarterial cardiopulmonary support and eCPR [8, 9]. These less-than-ideal success rates should improve over time as programs gain experience and implement guidelines and protocols, teams learn to function more effectively and efficiently, and patient selection and management improve. However, poor outcomes must also be tempered by the concerns that outcomes that are potentially "too good" might suggest that potentially salvageable but higher risk patients might not be offered therapy out of fear of experiencing a bad outcome. Nevertheless, it becomes the priority of a program to develop a "culture" of how aggressive they want to be with regard to offering therapy to high-risk (or low-risk) patients. Fortunately, scoring systems for venoarterial and veno-venous support indications can assist in patient selection. Again, outcomes and quality metrics must be benchmarked against similar programs, like institutions and established registries. Membership in the Extracorporeal Life Support Organization (ELSO: https://www.elso.org) is an important component of tracking outcomes and can play a key role in documenting program progress and success. In addition, membership can provide an opportunity to establish relationships with other programs to exchange ideas, share protocols, and have access to important and timely developments and technological innovations.

While the advances in the field of ECMO are rapid and there has been an equally rapid worldwide growth in programs and the number of patients supported, a key aspect of ECMO therapy is the ethical component of a highly invasive, resource-intensive, and complex intervention. Because ECMO is still associated with less than ideal outcomes, relatively high complication rates (including neurologic complications), and high resource intensivity (not to mention expensive, depending on the reimbursement circumstances which can vary dramatically), a fundamental question remains regarding not on whether we can offer and continue support, but

within an ethical and moral framework should we offer support. The chapter by Dr. Aultman on the ethics of ECMO therapy explores many of the difficult decisions and circumstances that providers often face when considering offering or continuing therapy in patients who would most likely immediately die if support is neither offered nor continued.

2. Conclusions

Experiences in the selection and management of patients with acute cardiac and respiratory failure who are treated with ECMO continue to grow. Recent trials continue to help demonstrate the effectiveness and role of ECMO as outcomes continue to slowly improve [10, 11]. Even though many patients treated with ECMO still die even in the best of circumstances, it remains important for everyone to continue to search for opportunities for improvement. Good outcomes must be embraced and shared with the entire team, as they can provide hope while also inspiring and motivating a team—even when there are concerns of futility (**Figure 2**). The goal of this volume is to offer further insights, experiences, and discussions of the current state of the art regarding many topics that challenge those who believed in the tremendous potential benefits of ECMO [12].

Figure 2.
BH (center in wheelchair) with his parents after qualifying for the finals in the single-scull, arms and shoulder only, rowing competition in the 2016 Paralympics in Rio de Janeiro. BH, a five-time US national champion in the event, represented the USA in Rio as a member of the Olympic team. In 2016, he was selected US rowing "rower of the year." several years prior, BH lost both legs to complications of a necrotizing soft tissue infection and required cardiopulmonary support with venoarterial ECMO due to overwhelming septic shock. Picture used by permission by all represented [11, 12] and adopted from volume 2 [13].

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Author details

Michael S. Firstenberg* and Jennifer M. Hanna
Cardiothoracic and Thoracic Surgery, The Medical Center of Aurora, Aurora, CO, United States

*Address all correspondence to: msfirst@gmail.com

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References

[1] Firstenberg MS. Introductory chapter: Evolution of ECMO from salvage to mainstream supportive and resuscitative therapy, extracorporeal membrane oxygenation. IntechOpen; 2016. DOI: 10.5772/64345. Available from: https://www.intechopen.com/books/extracorporeal-membrane-oxygenation-advances-in-therapy/introductory-chapter-evolution-of-ecmo-from-salvage-to-mainstream-supportive-and-resuscitative-thera

[2] Zapol WM, Snider MT, Hill JD, Fallat RJ, Bartlett RH, Edmunds LH, et al. Extracorporeal membrane oxygenation in severe acute respiratory failure. A randomized prospective study. Journal of the American Medical Association. 1979;**242**(20):2193-2196

[3] Bartlett RH, Roloff DW, Custer JR, Younger JG, Hirschl RB. Extracorporeal life support: The University of Michigan experience. Journal of the American Medical Association. 2000;**283**(7):904-908

[4] Bowling SM, Gomes J, Firstenberg MS. Neurologic issues in patients receiving extracorporeal membrane oxygenation support, extracorporeal membrane oxygenation. Advances in Therapy, IntechOpen. 2016. DOI: 10.5772/64269. Available from: https://www.intechopen.com/books/extracorporeal-membrane-oxygenation-advances-in-therapy/neurologic-issues-in-patients-receiving-extracorporeal-membrane-oxygenation-support

[5] Maul TM, Patricia Massicotte M, Wearden PD. ECMO biocompatibility: Surface coatings, anticoagulation, and coagulation monitoring, extracorporeal membrane oxygenation. Advances in Therapy, IntechOpen. 2016. DOI: 10.5772/63888. Available from: https://www.intechopen.com/books/extracorporeal-membrane-oxygenation-advances-in-therapy/ecmo-biocompatibility-surface-coatings-anticoagulation-and-coagulation-monitoring

[6] Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators, Davies A, Jones D, Bailey M, Beca J, Bellomo R, et al. Extracorporeal membrane oxygenation for 2009 influenza a(H1N1) acute respiratory distress syndrome. Journal of the American Medical Association. 2009;**302**(17):1888-1895. Epub 2009 Oct 12

[7] Firstenberg MS, Swaminath D. Left ventricular failure—Extra-corporeal membrane oxygenation: An update. World Society of Cardiothoracic Surgeons Journal. 2016;**1**(1):12-14

[8] Rastan AJ, Dege A, Mohr M, Doll N, Falk V, Walther T, et al. Early and late outcomes of 517 consecutive adult patients treated with extracorporeal membrane oxygenation for refractory postcardiotomy cardiogenic shock. The Journal of Thoracic and Cardiovascular Surgery. 2010;**139**(2):302-311, 311.e1

[9] Peek GJ, Mugford M, Tiruvoipati R, Wilson A, Allen E, Thalanany MM, et al., CESAR Trial Collaboration. Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): A multicentre randomised controlled trial. Lancet. 2009;**374**(9698):1351-1363

[10] Combes A, Hajage D, Capellier G, Demoule A, Lavoué S, Guervilly C, et al. Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome. New England Journal of Medicine. 2018;**378**(21):1965-1975

[11] Schmid C, Philipp A, Hilker M, Rupprecht L, Arlt M, Keyser A, et al. Venovenous extracorporeal membrane oxygenation for acute lung failure in adults. The Journal of Heart and Lung Transplantation. 2012;**31**(1):9-15

[12] Tulman DB, Stawicki SPA, Whitson BA, Gupta SC, Tripathi RS, Firstenberg MS, et al. Veno-venous ECMO: A synopsis of nine key potential challenges, considerations, and controversies. BMC: Anesthesiology. 2014;**14**:65

[13] Firstenberg MS, Hanna JM. Introductory chapter: ECMO-growing indications, applications, and understanding of a complex supportive therapy. Advances in Extra-Corporeal Perfusion Therapies, IntechOpen. 2018. DOI: 10.5772/intechopen.81777. Available from: https://www.intechopen.com/books/advances-in-extra-corporeal-perfusion-therapies/introductory-chapter-ecmo-growing-indications-applications-and-understanding-of-a-complex-supportive