Chapter 1

Introductory Chapter: ECMO - Growing Indications, Applications, and Understanding of a Complex Supportive Therapy

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Additional information is available at the end of the chapter

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1. Introduction

This volume represents the second in a series of texts focused on extra-corporeal membrane oxygenation (ECMO), also known as extra-corporeal life support (ECLS) [1]. Over the years, there has been a continuous evolution of this therapy from a salvage form employed only in extreme cases in which all other treatment options have failed to a technology which is now considered a critical component in the toolbox of therapies and technologies used for acute cardiopulmonary failure. While initial experiences reported few survivors, these poor outcomes clearly had multifactorial etiologies [2]. Difficulties with primitive pump and circuit designs and technologies, a poor understanding of which patients derive the greatest benefit from this therapy, little understanding of the long-term physiologic implications of patient-circuit biologic interactions, a lack of management guidelines, and a generally limited understanding of managing patients and therapy-related complications while on "longer" term cardiopulmonary bypass have all contributed to the complexities of successful implementation of ECMO into mainstream medical and surgical practices. Nevertheless, over the past three decades, there has been continued refinement in all aspects of ECMO therapies, with a growing understanding of the role of ECMO as a life-saving therapy and potential bridge to transplantation while awaiting organ availability. ECMO has evolved into a treatment option that allows for an acutely injured heart and or lungs to heal, either allowing for recovery or serving as a "bridge" to a more definitive long-term end-organ replacement option such as ventricular assist devices or cardiopulmonary transplantation [3]. Many of these complex topics are addressed in this contemporary volume. However, there remains, without a doubt, much more to learn and understand. The successes of the ECMO technology reflect the tremendous efforts, dedication, and commitment by providers and researchers at all levels who recognize the enormous potential for ECMO to save lives and present options to those who would otherwise have none [4].

This volume reflects the substantial work of those, worldwide, who have dedicated a tremendous amount of time and energy into better understanding of how to achieve better outcomes with this complex technology. The common theme of this work has been the recognition that teamwork is the most important variable that contributes to clinical success.

Developing a comprehensive "ECMO team" is one of the first steps in building a successful program. This team must be prepared to initiate therapy at any time and in any setting, from those as controlled as an operating room to those as chaotic as an emergency room. While the specific members of the team might vary from program to program, there are several key features that must be established in advance. It is well recognized that effective teams must communicate and work well together—there must be uniform trust and a collective value attached to the expertise that each member brings to the bedside. It likewise needs to be recognized that traditional medical and professional hierarchies might be considered "old-fashioned" and potentially ineffective, if not dangerous. Additionally, there must be a willingness to embrace the concepts of crew resource management (CRM). The foundation of CRM is that every member of the team has a voice and that each voice is valued and respected. All members of the team must be encouraged, if not empowered, to speak up, particularly when there are safety concerns. In the context of an ECMO team, membership must include all of the following related disciplines, including, but not limited to (and in no particular order of importance, as all are important):

- Surgeons (cardiothoracic, general, trauma, emergency medicine)
- Critical care intensivists (pulmonary, surgical)
- Medical specialists (infectious disease, neurology, cardiology)
- Perfusionists
- Pharmacists
- Nursing (bedside, advanced practice providers)
- Respiratory therapists
- Palliative care
- Hospital leadership and administration
- … and, most importantly, a Champion for the program to lead the team

As a function of the tremendous dedication of resources needed to establish a successful ECMO program, there must be a well-established network of support and encouragement from hospital administration and leadership (**Figure 1**) [5].

Increasingly, in medicine there is a recognition that optimal outcomes, especially with complex and high-risk interventions, can be achieved using simulation training to help prepare

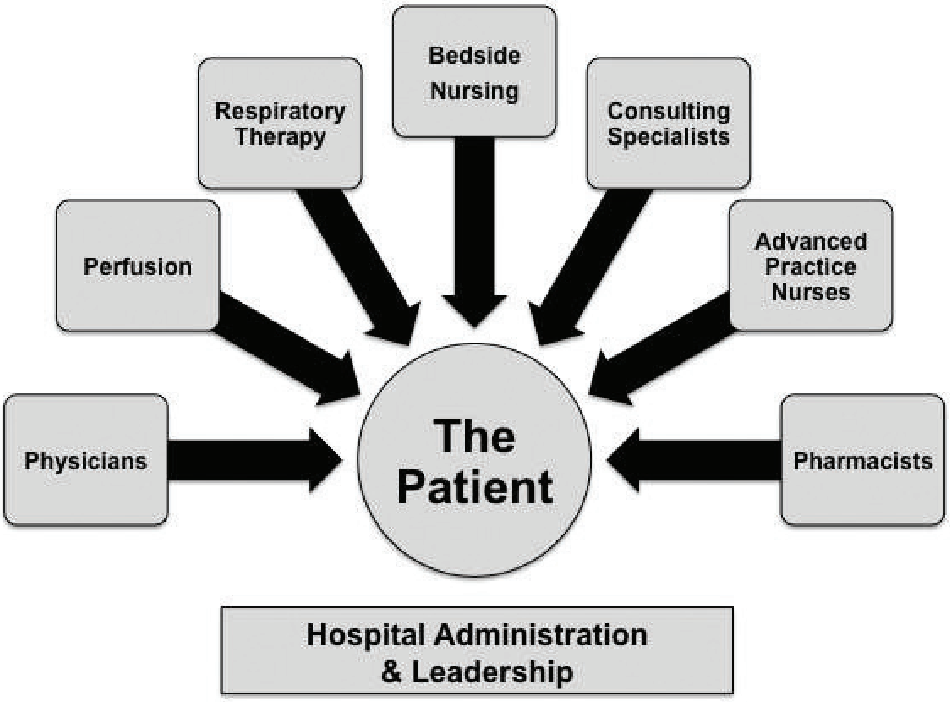

Figure 1. ECMO "team." Adopted from Reference intro chapter in Vol 1 (Ref [1]).

the team to respond in an effective and efficient manner. Especially in the case of time-sensitive therapies such as ECMO, in which minutes sometimes can determine an outcome, simulation training must be a component of every program and practiced regularly. In addition, the equipment and team must be prepared to implement this therapy at any time with established protocols, guidelines, and goals of therapy [6]. The chapter by Dr. Sin Wai Ching emphasizes and outlines these topics.

While patient selection is a critical aspect of ECMO therapy, determining the type of therapy to initiate and how is likewise paramount. In the previous text, some of the topics related to cannulation techniques [7] and pump/circuit design and development were addressed [8]. The chapter by Borrelli further elaborates on these technical aspects of pump/circuit design by outlining their 23-year experience with pump positioning and holder systems.

Regarding the specifics of patient selection and implementing ECMO therapy, it is important to understand how ECMO can (or should) be applied in specific clinical circumstances. Particularly, with regard to understanding the fundamental differences in veno-veno ECMO (VV-ECMO) for pulmonary support and veno-arterial ECMO (VA-ECMO) for cardiac or cardiopulmonary support, several chapters discuss general clinical topics related to the specifics of therapy. These include chapters in cardiogenic shock, severe acute respiratory distress syndrome, and generalized applications for longer-term support. More focused topics include:

- Primary graft failure after heart transplantation (Caneo)
- Post-cardiotomy cardiogenic shock (Murashita)
- Unusual applications in the newborn (Wintermark)
- Applications and support in high-risk percutaneous cardiac interventions (Ganyukov)

It cannot be emphasized enough that a key component to a successful program is appropriate patient selection. Despite all of the advances in ECMO therapies over the years, even successful programs have outcomes that range from 60 to 70% survival for veno-veno pulmonary support and 25–35% for veno-arterial cardiopulmonary and emergent cardiopulmonary resuscitation applications (E-CPR) [9, 10]. Lower success rates that improve over time and with experience, improvements in institutional protocols, and better (and more-timely) patient selection can be expected during the early phases of program development. Alternatively, as is seen with other areas of innovative clinical therapies, programmatic successes and improving outcomes spur attempts at treating higher-risk patients, resulting in a paradoxical loss in these successes. Programs with inordinately high success rates may be depriving salvageable patients the opportunity for survival because their indications are slightly out of the boundaries of the traditional indications for therapy. Programmatic attempts to support lower-risk patients on ECMO are not uncommon and are typically based on institutional (and personal) biases and outcomes. A series of successes with low-risk patients then rationalizes attempts to salvage the higher-risk patient. Conversely, lower than desired outcomes in higher-risk patients might then limit selection back to patients with low-risk characteristics. Regardless, institutional checks and balances as well as systems for reviewing metrics (clinical and financial) and outcomes should be established. Team engagement at all levels—from bedside nursing to top administrative leadership—is critical and cannot be emphasized enough. Membership and participation in the Extra-Corporeal Life Support Organization (ELSO: https://www.elso.org) should be encouraged, as it can provide data to help benchmark institutional success. Membership can also provide a community in which to partner with colleagues, exchange ideas, and as a resource for timely and important developments in the field.

Unusual patient populations represent one of the most rapidly expanding populations for ECMO. For example, early experiences with ECMO to support overwhelming septic shock in the setting of necrotizing soft tissues infections and the long-term, albeit anecdotal, good outcomes in this clinical scenario have prompted greater enthusiasm for otherwise potentially "hopeless" cases [11, 12]. There is also growing evidence supporting the role of ECMO to support high-risk catheter-based interventions, as discussed in the chapter by Dr. Ganyukov and colleagues [13]. However, such applications are limited to high-risk procedures in the catheterization laboratory, defined as those with impaired ventricular function and complex anatomy, or to reduce the risk of inherently high-risk or complex interventions, such as percutaneous aortic valve procedures (i.e., transcatheter aortic valve replacement), coronary or cardiac structural interventions, or electrophysiologic ablative procedures for complex arrhythmias. The key goal of providing ECMO support during these procedures is to reduce the risks of end-organ dysfunction. Hemodynamic instability (or even acute failure) during such procedures could be reduced by using ECMO to provide support for brief periods of time until the pathology is corrected (i.e., the coronary artery is stented or valve dilated) [14].

Managing patients on ECMO represents one of the greatest clinical challenges in all of medicine. Management on ECMO can be divided into several areas, and management decisions must be made in the context of the complex limitations of caring for patients on ECMO. For example, in many areas, there are little, if any, randomized evidence, established protocols, or even well-developed guidelines. Even simple interventions, like transporting patients on ECMO, require team-based decision-making regarding the potential risks and benefits [15].

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Nevertheless, there are growing data to support some of the challenging aspects of caring for ECMO patients. Some of these topics, while discussed in the first volume [1], are expounded upon in this text. Such examples include chapters on flow optimization and reduction of ventricular distention by Dr. Amarelli and the application and role of modified ultrafiltration in pediatric patients by Curi-Curi and colleagues.

As with any intervention on complex and high-risk patients, transparent, frequent, and honest updates and communications with the family are critical to managing expectations. It is always important to emphasize that all communications should focus on the reality that even in ideal circumstances, morbidity and mortality in patients needing ECMO continue to be high. However, despite potentially long post-ECMO hospitalizations and recoveries, survivors can potentially return to productive lives [6].

2. Conclusions

The goal of this text is to demonstrate further that ECMO continues to evolve as a mainstream therapy for patients experiencing acute, severe, medically refractory cardiac and/or pulmonary

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 USA national champion in the event, represented the USA in Rio as a member of the Olympic team. In 2016 he was elected 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 veno-arterial ECMO due to overwhelming septic shock. Picture used by permission by all represented [11, 12].

failure. Contemporary trials continue to define the role of ECMO as the search for better outcomes evolve [16]. However, as technology improves, guidelines get developed, protocols get refined, and experience grows, without a doubt, outcomes will improve [17]. ECMO, as a function of its invasiveness, need for substantial resources, and high-risk/high-reward, and novel technologies (i.e., the pump and oxygenators) often generates much institutional interest and intrigue. Unfortunately, many patients, despite such heroic efforts, die on ECMO—even when everything appears to have been done "right." As important as it is to learn from all outcomes, it is critical that everyone cherishes all victories. Victories can inspire, give hope, and motivate a team even when further treatments appear futile (**Figure 2**). Even though there is still much to learn on the topic of ECMO, the goal of this text is to continue to build on the growing foundation of experiences and the current literature. If nothing else, the hope is to help inspire those intrigued by and who believe in the potential benefits of ECMO [18].

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