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Simulation for neonatal extracorporeal membrane oxygenation teams

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ABSTRACT

Extracorporeal membrane oxygenation (ECMO) is a highly technical and complex method of life support. Patient and circuit emergencies on ECMO are rare, but in these cases, prompt and correct actions to address the crisis are needed to prevent morbidity and mortality. ECMO simulation programs have gained popularity in recent years, as they provide a standardized educational experience for all members of the inter-professional care team. In addition to providing a context in which to solidify knowledge of ECMO support, participants are also able to focus on vital technical and behavioral skills that are not highlighted in other training methodologies. ECMO simulation can also be used for quality improvement, clinical and educational research, and assessment/credentialing. Multi-organizational international collaboratives have formed, and are working to standardize ECMO education training across institutions; simulation will play an essential role in this process.

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Introduction

Simulation for extracorporeal membrane oxygenation (ECMO) has become an essential modality for education of the inter-professional ECMO care team, but in recent years the applicability of this technology has become much broader. This review will first describe the initial development of ECMO simulation, as well as the technical interface between the manikin and circuit, for both lower and higher technology equipment. Next we will discuss how ECMO simulation can be used for the following: initial and maintenance ECMO training for individuals and teams; research and quality improvement to enhance patient outcomes; novel applications; the potential role of simulation in ECMO assessment and credentialing; and future directions for collaborations, development, and research.

Background

ECMO is a technology that uses a mechanical circuit, including a pump and a membrane oxygenator, to support a patient's cardiac and/or respiratory function in the event where conventional support is inadequate. ECMO was developed in the 1970s, and is most often used in neonatology for patients with acute, potentially reversible causes of respiratory failure, including meconium aspiration syndrome, persistent pulmonary hypertension of the newborn, and congenital diaphragmatic hernia.¹ Overall, neonates placed on ECMO due to respiratory failure have a survival rate of 84% until decannulation, and of 74% until discharge.² Given the highly technical nature of this therapy, it is not surprising that mechanical or patient complications can be lethal. Per the recent report of the Extracorporeal Life Support (ECLS)

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registry, mechanical complications on ECMO may decrease survival rates to 44–71%, and survival rates after some patient complications are even lower.² Therefore, effective training strategies are imperative to ensure prompt, appropriate interventions to minimize patient death and morbidity.

Traditional ECMO education and training has been conducted primarily through didactic lectures, supplemented with “water drills” (when saline is pumped through a closed-loop circuit, and various emergencies are simulated without incorporating real-time changes in patient status) or animal laboratories (when a living animal is cannulated and placed on ECMO support). These strategies primarily involve passive learning, which is less desirable for adults, who benefit from active learning situations where one’s own knowledge, experience, and critical thinking skills can be applied to solve problems.³

Additionally, these methods focus mainly on cognitive and technical skills, and neglect vital behavioral skills. Human errors, such as inadequate communication, leadership, and team behaviors, contribute significantly to life-threatening events in many high-risk industries, including aviation and the military. The Institute of Medicine’s report “To Err is Human” brought to the public forefront the issue of medical errors in healthcare, and human factors training was recommended as a strategy to improve patient safety.⁴ Crew resource management (CRM) is one such program that was initially developed by NASA and the aviation industry as a way to improve flight safety through more effective communication, leadership, and decision-making of flight crews.⁵ These strategies have subsequently been adapted for use in other high-risk industries, including healthcare.

Neonatal ECMO simulation

Simulation allows learners to focus not only on the relevant content matter but also on procedural skills, critical thinking, behavior in stressful situations, and teamwork skills. Learners are immersed in realistic scenarios, respond as they would in their typical environment, and receive immediate feedback on their performance.⁶ Simulation was first applied to ECMO training in 2006.⁷ A neonatal manikin was “cannulated” and the proximal ends of the cannulae were connected via a loop of tubing. The distal ends of the cannula were connected to a saline-filled ECMO circuit. Alterations could be made to the patient’s status in real time by remotely manipulating vital signs on the bedside monitor. Circuit pressures were altered by manually adjusting the pressure control display on the circuit or by changing the volume of fluid in the system. In this manner, emergencies such as hypertension, hypotension, cardiac stun, cardiac tamponade, pneumothorax, air entrainment, decannulation, oxygenator clot, and raceway rupture were replicated with a reasonably high degree of fidelity.⁷

Anderson et al.⁷ surveyed 25 subjects who had completed both a traditional ECMO training course and a newly developed “ECMO Sim” program at Stanford’s Lucille Packard Children’s Hospital in the previous year. Subjects found the simulation-based program to be more relevant to their clinical practice, more effective in improving technical skills, and significantly better in improving confidence in managing

ECMO-related emergencies. “ECMO Sim” was rated higher on a Likert scale than the traditional ECMO training course, with a score of 44 ± 0.5 vs 25.6 ± 0.7 ($P < 0.001$). Additionally, participants spent significantly more time engaged in active learning (asking questions, speaking, or practicing procedures) during “ECMO Sim” compared to the traditional ECMO training course. These findings were received with excitement, and ECMO simulation has since been applied to education and training, as well as many other areas.

Equipment selection and adaptation

Manikins and technologies used for ECMO simulation are described as either low or high technology, and may have significant differences in the degree to which they simulate a real patient situation. Although commercially available high-technology ECMO simulators are under development,⁸ many models have been designed by individual institutions, and may incorporate commercially available perfusion simulators to address the needs of each specific training environment. Many institutions have chosen to use models similar to that described by Anderson et al.⁷ These low-technology models can be adapted to create most scenarios desired for the training and education of the ECMO multidisciplinary team. However, a number of authors have described high-technology approaches to ECMO simulation.

Lansdowne et al.⁸ described the use of the Orpheus perfusion simulator combined with a patient manikin to create an ECMO simulation model with a high level of fidelity. This is shown in Figure 1. The Orpheus perfusion system (Ulco Technologies, Marrickville, Australia) is a technology that has been used for simulation-based cardiopulmonary bypass training of perfusionists on heart-lung bypass systems. It provides physiologic information through the use of hydraulics to mimic a patient’s circulatory system’s response to changes in status. This ability to adjust pressures within the system allows the participants to diagnose and treat a simulated condition based upon realistic parameters. Although not intended for ECMO training, it can be adapted

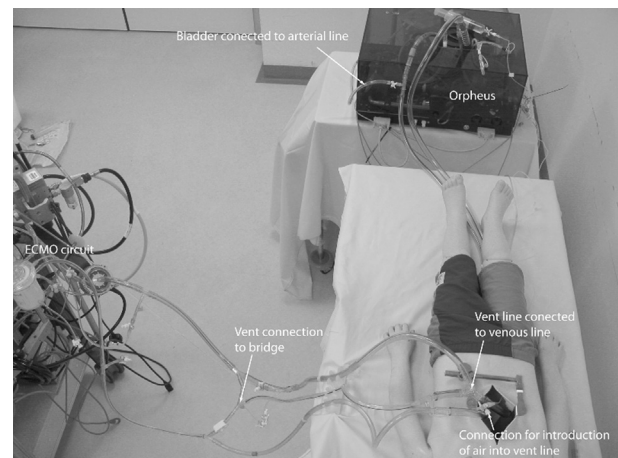


Fig. 1 – Incorporation of Orpheus perfusion simulator into ECMO simulation set-up. (Adapted with permission from Lansdowne et al.⁸)

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