The Journal of Emergency Medicine, Vol. 49, No. 4, pp. 552–560, 2015

0736-4679/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.jemermed.2015.02.010

Clinical Review

PEDIATRIC EXTRACORPOREAL MEMBRANE OXYGENATION: AN INTRODUCTION FOR EMERGENCY MEDICINE PHYSICIANS

Lynn P. Gehrmann, MD,* John W. Hafner, MD, MPH, FACEP,†‡ Daniel L. Montgomery, MD,§ Klayton W. Buckley, CCP, RN,‖ and Randall S. Fortuna, MD, FACS¶**††

*Department of Emergency Medicine, Ministry Medical Group Saint Mary's Hospital, Rhinelander, Wisconsin, †Department of Emergency Medicine, University of Illinois College of Medicine at Peoria, Peoria, Illinois, ‡Department of Emergency Medicine, Children's Hospital of Illinois at OSF Saint Francis Medical Center, Peoria, Illinois, §Emergency Medicine Residency Program, University of Illinois College of Medicine at Peoria, Peoria, Illinois, ‖Department of Perfusion, Children's Hospital of Illinois at OSF Saint Francis Medical Center, Peoria, Illinois, ¶Department of Pediatrics, University of Illinois College of Medicine at Peoria, Peoria, Illinois, **Extracorporeal Life Support (ECMO) Services, Congenital Heart Center, Children's Hospital of Illinois at OSF Saint Francis Medical Center, Peoria, Illinois, and ††Department of Surgery, University of Illinois College of Medicine at Peoria, Peoria, Illinois

Reprint Address: John W. Hafner, MD, MPH, FACEP, Department of Emergency Medicine, Children's Hospital of Illinois at OSF Saint Francis Medical Center, 530 NE Glen Oak Ave., Peoria, IL 61615

☐ **Abstract—Background: Extracorporeal membrane oxygenation (ECMO) therapy has supported critically ill pediatric patients in the intensive care unit setting with cardiac and respiratory failure. This therapy is beginning to transition to the emergency department setting. Objective of Review: This article describes the fundamentals of ECMO and familiarizes the emergency medicine physician with its use in critically ill pediatric patients. Discussion: ECMO can be utilized as either venoarterial (VA) or venovenous (VV), to support oxygenation and perfusion in respiratory failure, sepsis, cardiac arrest, and environmental hypothermia.**

☐ **Keywords—ECMO; extracorporeal membrane oxygenation; respiratory failure; pediatric; E-CPR**

INTRODUCTION

Extracorporeal membrane oxygenation (ECMO) is the use of a modified cardiopulmonary bypass machine that provides cardiac support, blood oxygenation, and carbon dioxide removal in patients with reversible cardiac or respiratory failure. In the neonatal intensive care unit (NICU), ECMO use has become standard of care with survival rates > 85% in neonates as a final rescue therapy, with severe and refractory hypoxemia secondary to meconium aspiration, respiratory distress syndrome, and primary pulmonary hypertension prompting uses from the neonatal population to the pediatric (1). Most of the literature on ECMO use with pediatrics relates to its use in the pediatric intensive care unit (PICU), but with this expanded patient selection criteria and simplified, more compact systems, ECMO is now a possible treatment option for more pediatric patients who are failing conventional treatment in the emergency department (ED). The purpose of this article is to review the evidence and describe the fundamentals of ECMO to familiarize the emergency medicine physician with this modality for the treatment of the critically ill pediatric patient.

DISCUSSION

History

The story of ECMO's transition from the NICU and the PICU to the ED is a complicated journey that spans

RECEIVED: 2 October 2013; FINAL SUBMISSION RECEIVED: 19 December 2014;
ACCEPTED: 17 February 2015

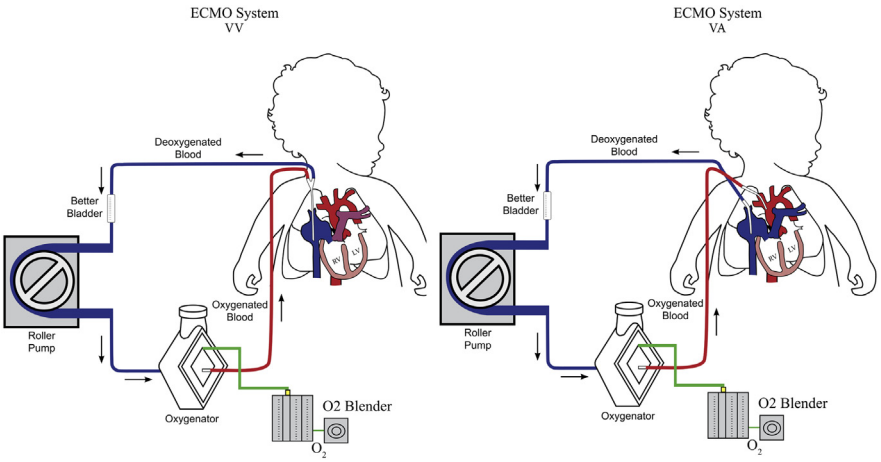

Figure 1. VV and VA ECMO circuits.

over several decades. ECMO is a mechanical technique that provides a circuit outside the body where blood oxygenation and carbon dioxide removal can occur for patients with reversible cardiac or respiratory failure. ECMO machines are a modified cardiopulmonary bypass circuit, conceptually similar to the one invented by John Gibbon in 1936 and in current use during cardiac bypass surgery in the operating suite.

One of the major modifications that expanded the use of the original historical bypass circuit was the addition of a silicone membrane in the 1950s that enabled prolonged use by limiting the direct interface between the blood and oxygen during cardiac surgery (2–5). In the 1960s there was extensive research on materials and techniques, with the goal to increase the length of time a patient could remain on bypass. The first reported successful use of extracorporeal circulation for a patient in acute respiratory failure was for the treatment of an adult blunt chest trauma patient in 1971 that developed acute respiratory distress syndrome (ARDS) after a motorcycle accident (6,7). This was the beginning of moving cardiopulmonary bypass from the operating suite to the bedside. In the early 1970s, the concept of intensive care units development and advanced care for patients with ARDS stimulated further research of bedside extracorporeal circulation techniques.

It was a few years later that Bartlett et al. reported success in treating the first newborn with respiratory failure, fostering the hope that there was a new possible therapy for the treatment of severe hypoxia (2,8). In 1974, a multicenter randomized trial was launched to test venoarterial ECMO vs. conventional mechanical ventilation therapy in adult ARDS patients. Unfor-tunately, the study revealed mortality rates in the ECMO therapy group as high as 90%, not significantly different from those in the conventional ventilator treatment group (9). These results decreased the interest of ECMO for adult ARDS therapy at the time, but utilization continued with neonates. In the late 1970s, neonates with respiratory failure treated with ECMO yielded survival rates of 56%. This success was attributed to the fact that in neonatal respiratory failure, the lungs require only a short time for recovery (9).

Subsequently, ECMO has been used in NICUs for the treatment of respiratory failure due to primary pulmonary hypertension of the newborn, meconium aspiration syndrome, persistent fetal circulation, and congenital diaphragmatic hernia, yielding survival rates of >80% (10). From the success in neonates, and supported by good evidence-based medicine for treatment of respiratory failure, the technology was adapted to pediatrics in the early 1980s. In 1989, the Extracorporeal Life Support Organization registry was founded. This registry has been able to track pediatric patients treated with ECMO and was able to document a cumulative survival rate of 53% in 982 cases of pediatric respiratory failure from 1990 to 1995 (11). The use of ECMO has continued to undergo multiple refinements and technical improvements, allowing for expansion of the patient selection criteria and an evolution from a rescue therapy to use as early intervention therapy and use in the ED.

The ECMO Circuit

ECMO is a complex therapy modality with two standard modes, venoarterial (VA) and venovenous (VV). Each mode uses the same basic circuit components, with placement of the cannulas determining the mode. The basic ECMO circuit is composed of vascular cannulas for access and blood return, circuit tubing, a pump, a gas-exchange device, a heat exchanger, and systemic anticoagulation with heparin to keep the system patent (Figures 1 and 2) (2,5,13). In VA ECMO, the circuit requires accessing a major vein and a major artery, whereas VV ECMO requires only access to either two major veins or a single major vein using a double-lumen catheter.