Education for Nursing Staff Caring for Extracorporeal Life Support Patients

by

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Abstract

The utilization of extracorporeal membrane oxygenation (ECMO) and extracorporeal life support (ECLS) has increased significantly over the past decade as measured by the number of cannulations and the number of institutions that are recognized as ECMO centers. The management methods and models utilized by hospitals vary significantly with some utilizing perfusionists for ECMO management and others utilizing nurses or respiratory therapists. When facilities utilize staff other than perfusionists for bedside management, it creates a high need for initial education of staff, continued competency, and program development. The purpose of this project was to develop recommendations for rapid and long term training plans for bedside nurses who care for ECMO patients but are not in an ECMO Specialist role as defined by the Extracorporeal Life Support Organization (ELSO). These recommendations were developed to ensure safe patient care and handling for ECMO patients.

A review of the literature determined that nurses (RN), specifically intensive care unit (ICU) RNs, are found at the bedside of all ECMO patients independent of the patient care model being utilized. Nursing has a high turnover rate, which has been exacerbated in recent times by the COVID-19 pandemic. In addition, the number of sites offering ECMO services and the number of patients receiving ECMO support continues to expand, leading to an increased need for hospitals to train new nurses quickly and safely, and support competency of their current staff. Additionally, as ECMO utilization increases, many hospitals choose to utilize management models that give RNs a larger role in ECMO patient care, thus placing a larger demand on the bedside RN. By reviewing the literature for current standards for long term education and for examples of rapid education models, a resource was developed to assist in the ECMO training of RNs in different staffing models and under various time constraints.

The focus of these educational training documents is the bedside RN who provides care for ECMO patients but is not in an ECMO specialist role as defined by ELSO. This project does present the standard of RN education for the ECMO specialist role; however, it also takes an in-depth look at role of the bedside RN in various staffing models. To this end it provides recommendations for the didactic content and length of initial ECMO education and continuing education, as well as recommendations for a rapid education model that can be utilized in times of extreme staffing shortages.

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Table of Contents

List of Figures

List of Tables

Nomenclature

CO_2: Carbon dioxide

ECLS: Extracorporeal life support

ECMO: Extracorporeal membrane oxygenation

ELSO: Extrcorporeal Life Support Organization

FdO_2: Fraction of delivered oxygen

ICU: Intensive care unit

LPM: Liters per minute

O_2: Oxygen

PCG: Primary care giver

RN: Registered nurse

RT: Respiratory therapist

SpO_2: Oxygen saturation as shown by pulse oximetry

STAT: Urgently

VA: Veno-arterial

VV: Veno-venous

1.0: Introduction

Extracorporeal Membrane Oxygenation (ECMO) and Extracorporeal Life Support (ECLS) are interchangeable terms for a complex and high-risk therapy that provides cardiac and/or respiratory support for patients in cardiac or respiratory failure. ECMO can be utilized in a variety of scenarios by tailoring cannulation location and circuit components to best support a patient's acute needs. According to the Extracorporeal Life Support Organization (ELSO), ECMO utilization is increasing at a rapid rate in both the number of cases and the number of recognized centers [1]. Hospitals can see an increase in patients requiring ECMO due to either increased provider willingness to initiate therapy or due to an increase in the need for therapy caused by external circumstances, such as the COVID-19 pandemic. In the presence of increased ECMO cases, there is an increased demand placed on the healthcare team to manage these patients.

Institutions often develop their own model of care for ECMO patients, and these models can vary substantially regarding who manages the patient while they are in the intensive care unit (ICU) [2]. For example, some institutions utilize a model where a perfusionist manages the ECMO circuit at the bedside and stays with the patient at all times [2]. Other centers utilize an ECMO Specialist or bedside nurse (RN) to provide the same bedside management [2]. Under models other than the traditional perfusion management model, the ECMO specialists or RNs manage most of the patient care and perfusionists may do regular checks on the patients and are called in for transports, complications, ambulation, or for additional support. Each model has its own benefits and drawbacks; however, independent of the model adopted, the importance of developing a

training plan for all members of the healthcare team is vitally important to patients' safety and improving ECMO outcomes.

The goal of this project was to assist both individuals and facilities in the process of implementing, or improving, both a long term and a rapid education plan that ensures safe patient handling and care for ECMO patients especially as they transition care models due to an increase in ECMO volume [3, 4]. This was accomplished by evaluating the current ECMO utilization trends and evaluating the most common patient care models to establish guidelines for choosing the most appropriate care model based on current needs and resources. Evaluation of the various models for safety, cost, and staffing considerations, as well as identifying resources that are currently available, and standards for nursing education allowed for the development of recommendations for both long term and a rapid education for bedside RNs caring for ECMO.

2.0: Background

2.1: ECMO Utilization Trends

Over the last decade, the utilization of ECMO has increased significantly both in the number of cannulations and in the number of facilities that are equipped to provide this high level of patient management [1]. The Extracorporeal Life Support Organization (ELSO) documented an increase in ECMO runs by 530% from 2010-2020 (3446 versus 18260) and an increase in recognized centers by 282% (185 versus 521) over the same time frame (Figure 1) [1].

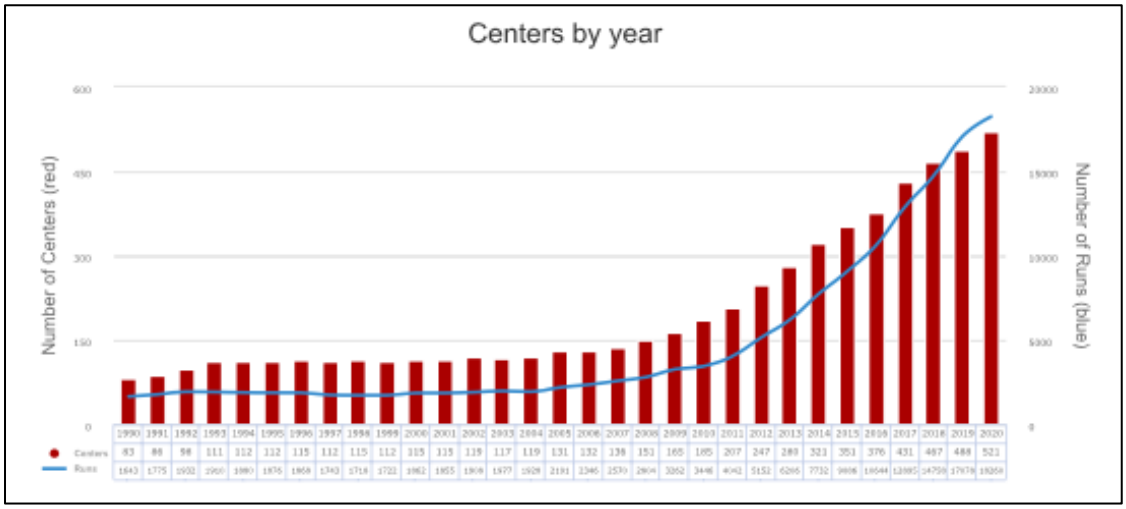

Figure 1: Number of ECMO Centers and ECMO Runs from 1990 to 2020 [1].

There are several reasons why a patient may have ECMO therapy initiated. A breakdown of the 2008-2014 data in the National Inpatient Sample Database (total of 17,000 patients) shows that the most common reasons for ECMO initiation are: 47.4% respiratory failure, 38.6% postcardiotomy, 5.5% lung transplantation, 5.3% cardiogenic shock, and 3.2% heart transplantation (Figure 2) [5]. With the current COVID-19

pandemic it is reasonable to assume that the fraction of ECMO patients with respiratory failure is likely higher than that reported in 2014, which also supports a growing number of ECMO cases.

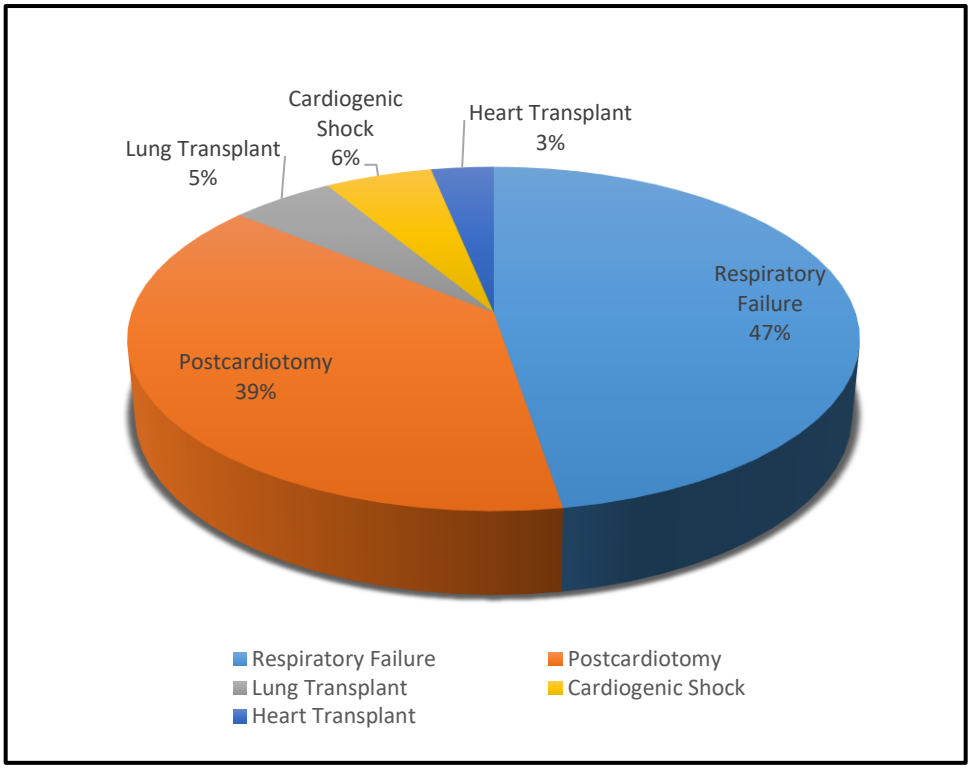

Figure 2: Reasons for ECMO Initiation in Years 2008-2014 [5]. From The National Inpatient Sample Database of patients from 2008-2014, "Reasons for ECMO Initiation."

2.2: ECMO Management Models

There is a significant amount of variability within the practice of ECMO patient management that appears to be driven primarily by a center's ECMO volume and their available resources. Management of ECMO tends to fall into three main models: the Traditional Model, the ECMO Specialist model, and the Primary Caregiver (PCG) model, also referred to in the literature as the single care giver model. The different models and the roles of each member can be compared in Table 1 and Figure 3.

Table 1: Description of ECMO Management Models. Abbreviations: ECMO- Extracorporeal Membrane Oxygenation, ICU-Intensive Care Unit, RN-Registered Nurse, RT- Respiratory Therapist.

Model:	Perfusionist:	ECMO Specialist:	Nurse:
Traditional Model	Sits at the bedside (or in the ICU) at all times caring for all aspects of ECMO.	N/A	Provides normal patient care with either minimal ECMO training, or no special training.
ECMO Specialist Model	Respond to emergencies, provide additional support for specialists, and help with risk events if the ECMO specialist needs assistance.	An RN or RT with advanced training sits at the bedside, (or in the ICU) at all times caring for all aspects of ECMO. Calls Perfusionist for emergencies, additional support, or high-risk events.	Provides normal patient care with either minimal ECMO training, or no special training.
Primary Care Giver Model	Respond to emergencies, provide additional support for specialists, and help with risk events.	N/A	Provides wholistic care for the patient including ECMO specific management and care. RNs are trained in specific aspects of management and emergency response but call perfusion for emergencies, support, or high-risk events.

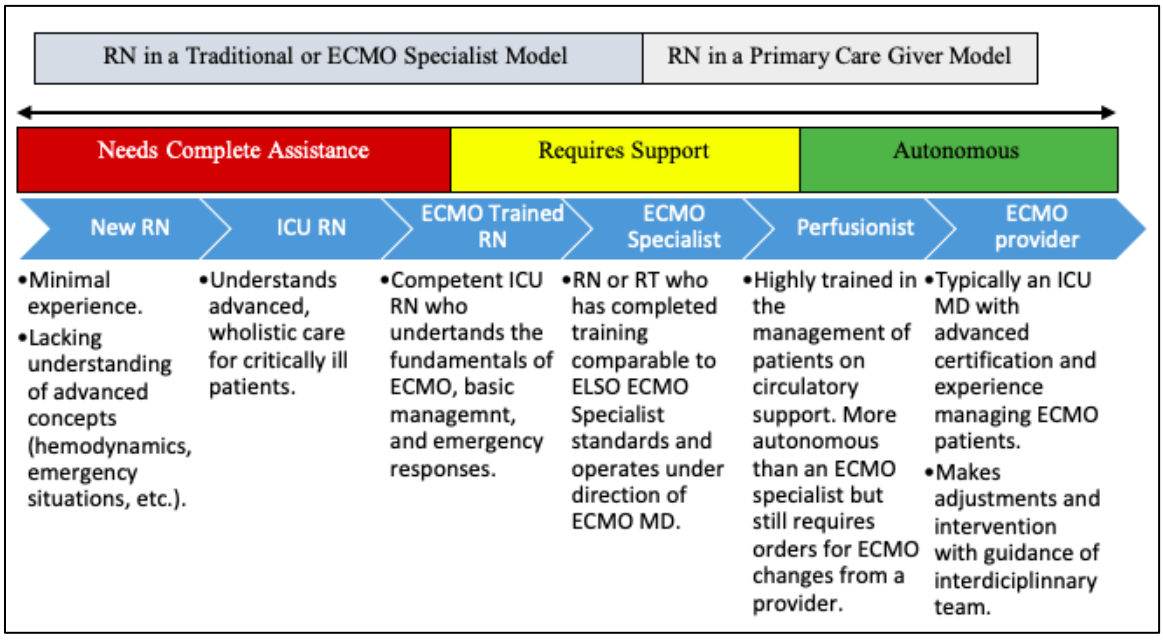

Figure 3: Description of the Various Roles in ECMO Management and Their Level of Autonomy.

There is a spectrum of RN autonomy across the management models that ranges from the bedside RN being fully trained as an ECMO Specialists and able to make changes to therapy, access the circuit, and perform more advanced intervention and troubleshooting to the RN only being trained in specific aspects of ECMO patient management, circuit basics, and basic emergency responses. This spectrum is illustrated in Figures 3 and 4. In most PCG models, a perfusionist or ECMO specialist will still round on the ECMO patient at set frequency to perform more advanced checks on the patient and circuit. A perfusionist or ECMO specialist would also be available in the hospital for any high risk events or emergency situations. Each model has its own unique benefits and drawbacks and can be used appropriately and safely in the right settings with the appropriate support.

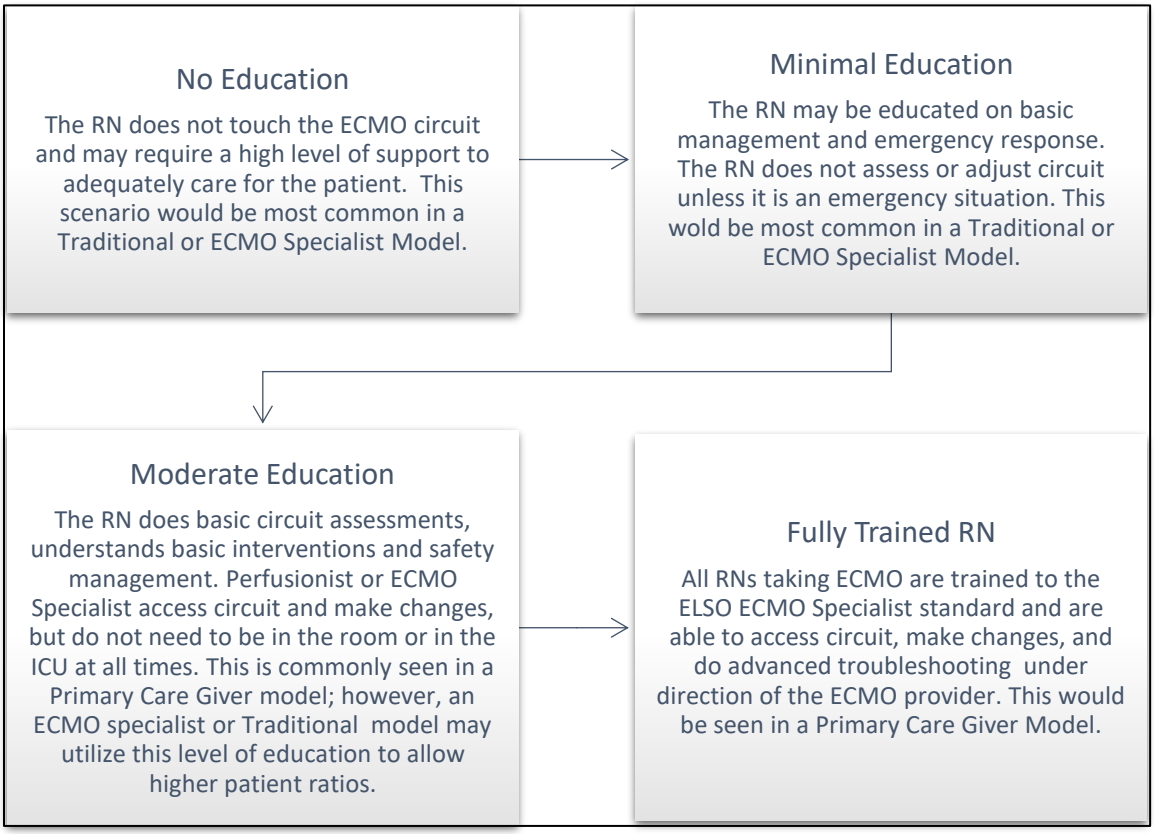

Figure 4: The Scope of Practice for RNs Based on Level of ECMO Education.

The traditional model was commonly used when ECMO was a relatively new therapy and when ECMO volume remained low within an institution. It utilizes perfusion staff members to manage the pump and guide care while the bedside nurse cares for all other aspects of the patient's care. The perfusionist stays in the ICU with the ECMO patient, or a ratio of patients, at all times. For example, some centers are comfortable having one perfusionist in the ICU for every four patients on ECMO. In this model, the RN is present and operates within their scope of practice and performs their normal duties with the added help and input from the ICU physician and the perfusionist. The strengths of this model are that it provides a high level of patient safety because perfusionists are well trained to handle the ECMO care for such patients. Non-perfusion staff are less likely to be knowledgeable about monitoring and managing certain aspects of ECMO therapy or to know how to troubleshoot complications as well as a perfusionist. The drawbacks of this model are that as ECMO volume increases, the cost to the hospital and patient increases. It also, as ECMO patient numbers rise, places an increased demand on the perfusion staff that may not be sustainable, and may lead to lost time in the operating room for cardiac surgeries.

The primary caregiver model uses another member of the healthcare team to provide care for the ECMO patient. A 2007 survey found that ECMO teams were most commonly composed of nurses (84%), followed by respiratory therapists (RT) (71%), perfusionists (32%), and others (3%) (Figure 5) [6], indicating that the primary caregiver model is the most common way of staffing ECMO. One reason why it might be so common is that it provides a lower cost [6, 7, 8]. It also generally decreases the demand placed on perfusion staff. The primary drawback to this model, and the primary barrier to

moving to this model, is the increased education requirements and staffing demands placed on the ICU staff to provide safe, high level, care.

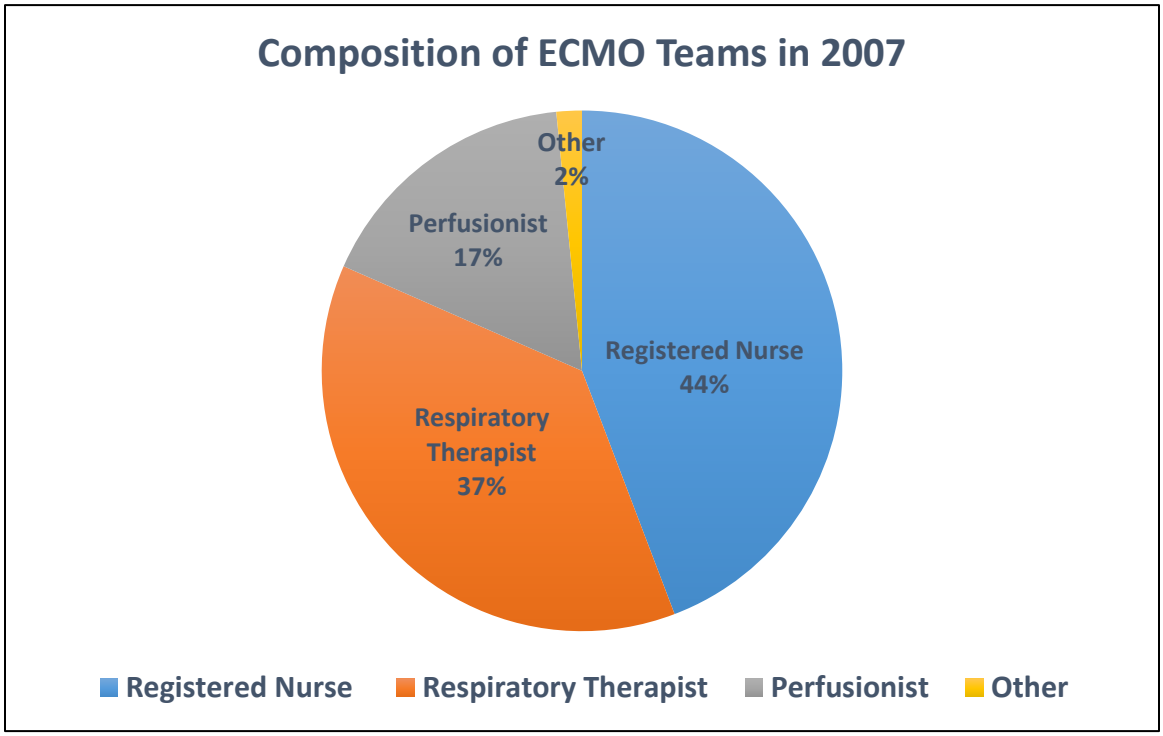

Figure 5: Percentage of ECMO Teams by Profession in 2007 [6].

As stated earlier, there remains a large amount of variability within institutional policies for ECMO management due to a lack of required standardization in this area. This lack of standardization is most likely present to allow sites to develop unique, tailored approaches for safe, effective, and cost-effective patient management. ELSO is the only organization that distributes guidelines for required institutional changes and education content; however, these resources are directed at centers who are seeking certification [9, 10]. ELSO certification is not a requirement to utilize ECMO and therefore centers are not required to adhere to these recommendations. There are safety

standards in place for general patient care from organizations such as the Food and Drug Administration, Center for Medicare and Medicaid, and the Joint Commission. These groups focus on patient safety, reimbursement, and standards for therapy and device utilization, but these standards are not necessarily tailored to ECMO management [11, 12, 13]. For example, the FDA only recently approved specific ECMO components for uses longer than 6 hours due to the increased utilization of ECMO during COVID-19. This is in spite of the average duration of ECMO therapy being 4 days, which is 24 times longer than the FDA approval [13, 14]. Considering the lack of standardization for roles and required education, developing a model that is tailored to a hospital's current and future needs is the most important consideration when deciding on a model.

2.3: Factors Important in Choosing an ECMO Delivery Model

2.3.1: Safety

When comparing the efficacy of various models, patient safety should be at the forefront of decision making. Since centers most commonly move away from a bedside perfusion model to a primary caregiver model, safety measures are most often reflected in a comparison between the center's outcomes under each model. This essentially uses the bedside perfusion model as the gold standard of care, which speaks to its efficacy; however, the fact that centers most often move away from the same model as they grow speaks to its limitations. Multiple studies looked at patient outcomes when transitioning models and found no differences. Freeman *et al.* saw no change in outcomes when transitioning the ECMO care model from a bedside perfusion model to the PCG model [6] and Cavarocchi *et al.* reported no change in outcomes in a single institution analysis

of transition over two years into a PCG model [7]. In contrast to transitioning models, Hamad General Hospital in Qatar first utilized ECMO in 2014 with a PCG model and reported outcomes on par with internationally reported standards [8].

2.3.2: Cost

ECMO is an asset vital to providing patients with the highest level of care possible. Initiating and managing therapy is costly such that attention is paid to adding cost efficiencies when possible. Each health care system, or specific facility, needs to consider several factors when identifying true costs of performing ECMO. These include: the pump, disposable, and the hourly salary of either a perfusion, or ECMO specialist, and the RN. The true price must include factors such as the hours of education required by the PCG model, any increase in ICU staffing needs, and the need to continually train new staff and ensure the competency of current staff.

ECMO volume is an important determinant for deciding on a staffing model for two main reasons. First, low volume centers can struggle to give staff adequate exposure and training such that they may not feel adequately prepared for ECMO administration. Second, as volume increases the cost of having a perfusionist at the bedside becomes significantly higher than that of an ECMO specialist or RN. This is both because perfusionists generally earn higher salaries than ECMO specialists and RNs as well as the lost ability for the perfusionist to support surgeries. If perfusion staffing is inadequate, this can lead to less cardiac surgeries and loss of reimbursement for those services. Additionally, an RN is still present bedside in both models. This means that calculating cost differences between models requires consideration of the perfusionist pay and lost OR opportunity, the time the RN is paid for education and additional training as well as

the wage of additional staff who are needed to support either patient care or education (RN educators, ECMO coordinator, etc.). A 2018 review of current staffing models by O'Connor and Smith found that centers who had less than five ECMO patients a year typically stayed with a 2:1 bedside perfusion model, whereas large volume centers that saw more than 30 ECMO patients per year chose to utilize a PCG model with an RN or RT in the ECMO specialist model [15]. When moving to an RN ICU management model, Freeman *et al*. reported a 61% decrease in cost for a moderate to high volume center (28 cases year 1 and 46 year 2) [6]. Dhamija *et al.* identified 10 cannulations lasting 10 or more days as the point where the cost of a bedside perfusion model is higher than that of a PCG model [16].

2.3.3: Staff Turnover

Maintaining a well-trained, competent staff is vital to both the bedside perfusion and PCG modes. A 2019 survey of perfusionists in the U.S. found the perfusion turnover rate to be 14.7% [17]. The primary reason for turnover identified in this survey, other than accepting a new position, was increase in workload; responses further identified the most common increases in workload to be more CPB cases and more ECMO. Interestingly, change in staffing model was present, but far less common [17]. The latest numbers published in the NSI National Health Care Retention and RN Staffing Report for 2021 indicates an 18.7% turnover rate for critical care nurses, and 27.3% for all new nurses [18]. Understanding the state of health care staffing and the need to not only continually train new staff, but to also maintain trained staff, is invaluable to a PCG model.

2.3.4: The Role of the ECMO Specialist

There is one important distinction that must be made within the topic of ECMO care models: the difference between the role of the ECMO specialist and that of the bedside nurse. The role of the ECMO specialist as described by ELSO is "…the technical specialist trained to manage the ECMO system and the clinical needs of the patient on ECMO under the direction and supervision of a licensed ECMO trained physician" [9]. Additional requirements for this role are that the individual must be certified as an RN, RT, perfusionist, or MD, they must have completed 24 to 36 hours of didactic teaching, 16 to 32 hours of bedside training, 8 to 12 hours of wet lab or animal laboratory session, and pass a written exam and skills evaluation [9]. Following this initial certification, ECMO specialists must attend regular team meetings and water-drills, provide a minimum hours of pump time established by the hospital, and pass an annual competency exam [9]. The process of becoming an ECMO specialist is extensive and requires a large commitment of time from the individual and resources for the center. Because of this, many centers will have perfusionists, MD, RN, or RT in the role that are not the primary caregiver for the patient but regularly round on patients, make changes to the circuit, and respond to emergencies.

The distinction between the bedside RN and the ECMO specialist is vital because it establishes that the ECMO specialist education standards are not necessarily applicable, or realistic, for the bedside nurse. Similarly, if a center utilizes a bedside perfusion model, the bedside RN is not the one responsible for the circuit and they are not required to have the same level of expertise and training as the perfusionist. Considering this differentiation, there remains a significant need to train and educate the bedside RN in

several aspects of ECMO management and patient care. This is true for any care model that may be utilized but is especially important when using a PCG model that utilizes the ECMO specialist's role, or a bedside perfusion model that utilizes a ratio of perfusionists to circuits. In these circumstances, the bedside RN spends more time with the patient than any other discipline and will, in most instances, be the first person present in an emergency or the first person to notice important changes in patient condition.

2.3.5 System Education and Buy-In

Some aspects of education are not discussed in depth in this document because they do not directly pertain to the individual caring for ECMO patients; however, the importance of system buy-in and system education when starting or maintaining an ECMO program cannot be understated. Top-down education of all personnel from surgeons and ICU providers to RNs, RTs, Certified Nursing Assistants, transporters, and imaging technicians is necessary to provide patients with the best care possible. Additionally ensuring that there is buy-in and understanding from management and financial service lines is necessary due to the large financial and personnel demands that can be placed on a system during this process.

2.4: Project Statement

The staffing model for ECMO management commonly changes as the number of ECMO cases at a site grows. A major challenge in this transition is educating the nursing staff who spend a significant amount of time with the patient in all models. The goal of this project is to assist both individuals and facilities in the process of implementing, or improving, both long term and rapid education plans that ensure safe patient care for ECMO patients [3, 4]. The aim for this resource is to be especially useful when

experiencing an increase in ECMO volume or a decrease in adequately trained staff. The result of this project is meant to be a resource that is especially useful to centers who are either initiating RN training programs, changing ECMO staffing models, or are experiencing an increase in ECMO volume and need to quickly increase the number of trained staff members.

3.0: Methods

To address the critical need for training through the development of applicable materials, several steps were taken. First, a Google web search for readily available ECMO training resources was performed. This helped to identify the availability, price, and time frames associated with third party training. This was accomplished by searching “ECMO training,” “Extracorporeal Membrane Oxygenation Training,” “ECMO specialist training,” and “ECMO course.” The web results were then evaluated to determine if the course or class was a general, wholistic education class that could be used for initial training. Classes that were specialized to focus on specific topics and not overall management and patient care were excluded.

Next, a literature review was performed to find guidelines for ECMO education to identify what education looked like in an ideal scenario. Because ELSO is the only certifying ECMO organization, their education standards were included; however, since their guidelines directly apply to the ECMO specialist, additional searches for “Nursing ECMO education," "initial ECMO education,” and “ECMO education for bedside nurses” were also completed. Searches were conducted in the Milwaukee School of Engineering Library’s Summon Discovery Service.

An additional review of the literature was then conducted on institutional ECMO training with a focus on those who utilized a rapid ECMO training model. Journal articles were searched with the terms “ECMO training,” “ECMO specialist training,” “rapid ECMO training,” and “accelerated ECMO training.” The results of these studies were evaluated to compare patient outcomes.

After reviewing the literature for best practice as well as establishing the efficacy of rapid education, it was possible to develop recommendations for long term and accelerated training of bedside RNs. In order to make recommendations for accelerated training, the minimum didactic content and hands-on training durations required to maintain safety were considered. Along with this, the background of the RNs who would participate in such training was also taken into consideration. When developing recommendations, the didactic content requirements should, in theory, still reflect those required for initial education for RNs. The duration of rapid training, and the selection of RNs who were able to participate in such training, are two factors that will be looked at more closely in order to develop a model that shortens training duration while maintaining patient safety.

4.0: Results

4.1: Existing Resources

There are several resources available for ECMO education at both individual and institutional level. Organizations such as Innovative ECMO Concepts [19], Thomas Jefferson University [20], ELSO [21], ECMO Advantage [22], and Specialty Care [23] all have comprehensive educational offerings and are readily accessible with a simple web search. Pricing for institution level education was unavailable due to the variability in institutional needs; however, individual pricing for introductory comprehensive ECMO course are listed in Table 2.

Table 2: ECMO Training Classes and Cost.

Course	Description	Cost
Innovative ECMO Concepts Adult ECLS Course [19]	This course is online, self-paced, and includes access to content for one year.	$2000
Thomas Jefferson University ECMO Specialist Training [20]	This is a two day, in person course that includes simulation.	$2000
ELSO's Adult ECMO Management Course [21]	This a two-day virtual course.	$1500
ECMO Advantages Comprehensive ECMO Training Course [22]	This is a three-day blended course that includes self-paced modules prior to the in-person sessions as well as simulation.	$2100
Specialty Care On-site Learning Track [23]	This is an in person two-day course that includes simulation.	$3000

The average price to educate one individual from this sample of third-party educators is $2120, which is not inconsequential when considering the need to educate a relatively large number of staff to provide round-the-clock staffing for an ICU. Further, one must take into consideration the roughly 18% turnover rate for ICU RNs, the need to

pay for the initial education of new staff and the re-education, or continuing education, of existing staff to ensure competency. These factors may drive institutions to develop their own education resources instead of utilizing a third-party resource. When determining how to educate staff to care for ECMO patients, the scale and duration of education should be seriously considered prior to committing to either developing an in-house education program or utilizing a third party. An institution's management model must also be taken into consideration to evaluate if the level of education provided by these courses is appropriate for all nursing staff, or if it is more in line with the education necessary for those in the ECMO specialist role.

One resource that is available through ELSO and may be a more appropriate resource for educating RN staff that are not in the ECMO specialist role, is their ECMO 101 Course [24]. This is a free online course that includes six modules and takes approximately 6 hours to complete. It covers the following topics: introduction and history of ECMO, indications and evidence for ECMO, the ECMO circuit, physiology of ECMO, general patient management during ECMO, and common scenarios and complications during ECMO [24]. This course is accessible for anyone, and only requires that they register an email address with ELSO and answer some demographic questions prior to receiving access. This course provides a good didactic foundation but would require the addition of hands-on time with an ECMO circuit.

There are also some free online resources for ECMO training; specifically, there are several videos available as of January 2022 on YouTube. The ease of access to high level education on this platform could be viewed as an excellent resource; however, there are several issues that arise when utilizing resources of this kind. Specifically, there is

little to no accountability for the creator of the resource to distribute accurate information or update the content as best practice changes. Because of this, these resources were not considered appropriate for institutional teaching; however, recognizing that there may be an opportunity to streamline teaching by utilizing recorded content is now an acceptable method of education. Online formats are incorporated into many of the third-party trainings referenced in Table 2, and this delivery method may become more prominent in the future.

Should an institution desire to develop in-house education, they may choose to utilize a consultant, partner with an existing center that has experience in developing pertinent curriculum, or to use the ELSO guidelines for education of ECMO specialists. This latter resource is a widely available and comprehensive resource that details educational standards for ECMO specialists [9]. Since each center has different needs, such as time frame of program development, financial resources, and in-house resources, there is room for customization in the method of developing the program. The standards and expectations for education will be explored in depth in the long term education section.

4.2: The Nursing Education Gap

In the review of the literature, it became evident that there is a significant gap in the standardization of both initial and continuing education for RNs who are not in the ECMO specialist role. There is an abundance of resources for the development and validation of ECMO simulation, and additional resources for education were found to focus on new MDs and advance providers, but not for the RN staff who directly care for these patients. Only one article was found that directly pertained to this group, and it utilized two courses, a basic safety course and an advanced user course, as the foundation for RN education [25]. The description of these courses is included in Table 3.

Table 3: Description of Suggested RN ECMO Education 2020 [25].

Course	Didactic Content	Simulation Description	Duration
Basic Safety Course	The purpose of the basic safety course was to provide ICU nurses with an understanding of ECMO fundamentals and important safety considerations including: the definition of ECMO, configurations, indications and contraindications, circuit components and physiology, and patient and circuit safety This course served as the minimum requirement for ICU nurses to directly care for a patient receiving ECMO and was a prerequisite to the advanced user course.	This course utilized low-fidelity simulation during which circuit components and a circuit safety checklist were reviewed and ECMO circuit emergencies were presented.	1 hour of didactic material and 1 hour of simulation
Advanced User Course	The advanced user course employed learning based on case scenarios to reinforce the foundational knowledge gained during the basic safety course and to exercise applied learning. Fundamental concepts were reviewed, and higher-level concepts were introduced. These higher-level concepts included approaches to mechanical ventilation in patients with respiratory failure receiving ECMO and hemodynamic considerations in patients with cardiac failure receiving ECMO.	Employed high-fidelity simulation to perform a mock cannulation. The goal of the mock cannulation was to provide exposure to the cannulation process while highlighting the important nursing consideration.	1 hour of didactic material and 1 hour of simulation

There appears to be a recognized need within the community regarding the need for standardization of education and the development of curriculum for this group of RNs. In June of 2021, the Nursing Professional Advisory Committee, a division of Israel's Ministry of Health, distributed the recommendations regarding nursing care for patients on ECMO, which can be seen in their entirety in Table 4 [26]. Most pertinent to this document, they identified the need to provide appropriate content for the various training programs available, such as generic, above-basic, and clinical specialization programs for RNs [26]. Additionally, in 2020, ECMOed, a taskforce brought together by ELSO in 2018, published a position paper on global ECMO education and an agenda for the future [27]. In this paper, they identify actionable items for future development, including "the creation of a standardized extracorporeal membrane oxygenation curriculum" and "defining criteria for an extracorporeal membrane oxygenation course as a vehicle for delivering the curriculum" [27]. All the actionable items identified by the ECMOed taskforce can be seen in Table 5. The fact that this gap is being recognized globally is promising for future of ECMO care, yet at the current time, this gap in RN education remains both real and relevant.

Table 4: Recommendations from the Professional Advisory Committee on Nursing Practice in the Care of ECMO–Supported Patients 2021 [26].

1) Determining the boundaries of RNs' professional authority and responsibility, including a description of activities that fall under the auspices of different professional ranks of RNs (e.g., generalist RNs and advanced practice RNs).
2) Providing appropriate content for the various training programs available, such as generic, above-basic, and clinical specialization programs.
3) Defining quality measures/indexes for treating ECMO-Supported Patients.
4) Implementing professional guidelines.

Table 5: Actionable Education Items Identified by the ECMOed Taskforce 2020 [27].

1) The creation of a standardized extracorporeal membrane oxygenation curriculum.
2) Defining criteria for an extracorporeal membrane oxygenation course as a vehicle for delivering the curriculum.
3) Outlining a mechanism for evaluating the quality of educational offerings.
4) Utilizing validated assessment tools in the development of extracorporeal membrane oxygenation practitioner certification.
5) Promoting high-quality educational research to guide ongoing educational and competency assessment development.

4.3: Long Term Education Program

The development of a long term educational plan for a hospital needs to include a plan for both initial education of staff members and another for re-education and continued competency. ELSO has produced a comprehensive guide for education entitled *The ELSO Guidelines for Training and Continuing Education of ECMO Specialists*, which is a comprehensive resource for education topics. Table 6 features a summary of

the didactic education topic requirements for new centers, Table 7 summarizes the wet and animal lab requirements for new centers, and Table 8 summarizes both the education and lab requirements for experienced centers. The document in its entirety can be found in Appendix A. Should an institution desire to utilize a PCG model where the bedside RN is able to manage the ECMO circuit relatively autonomously, under only the direction of an ECMO trained physician, every RN would need to be educated to the standards outlined in Tables 6, 7, and 8. As discussed in Section 2.3.4: The Role of the ECMO Specialist, the commitment to provide this level of education to all RN staff will require significant time, energy, and resources to both implement initially and maintain long term.

Table 6: ECMO Specialist Didactic Course Topic Content [9].

Introduction to ECMO	History, current status, indications, risks and benefits, membrane gas exchange physics and physiology oxygen content, delivery and consumption shunt physiology, types of ECMO, and future applications research.
Physiology of the diseases treated with ECMO	Persistent pulmonary hypertension, meconium aspiration syndrome, respiratory distress syndrome, congenital diaphragmatic hernia, sepsis/pneumonia, post-operative congenital heart disease/heart transplantation, cardiomyopathy/myocarditis, ARDS, aspiration pneumonia, and pulmonary embolism.
Pre ECMO Procedures	Notification of the ECMO team, cannulation procedure, open and percutaneous initiation of bypass, and responsibility of team members.
Criteria and contraindications for ECMO	Patient selection, selection criteria, and Pre-ECMO evaluation.
Physiology of coagulation	Coagulation cascade, activated clotting times (ACT's), disseminated intravascular coagulation, blood products and interactions, blood product management of the bleeding patient, blood surface interactions, laboratory tests, heparin pharmacology, use of Amicar, Protamine and other drugs.
ECMO equipment	Circuit priming, oxygenator function and blood gas control, ECMO circuit design, ECMO circuit components (cannula, pump, venous return monitor, in-line saturation monitor, pressure monitor, heater, hemofilter, bubble detector).
Physiology of VA and VV ECMO	Indications, physiology, advantages, and disadvantages.
Daily Patient and Circuit management on ECMO	*Patient:* Fluid, electrolytes, and nutrition, respiratory, neurologic, infection control, sedation and pain control, hematology, cardiac, and psychosocial. *Circuit:* Aseptic technique, pump/gas flow, pressure monitoring, blood product infusion techniques, circuit infusions, management of anticoagulation, circuit checks, and hemofiltration set-up.
Emergencies and complications during ECMO	*Medical*: Intracranial and other hemorrhage, pneumothorax/pneumopericardium, cardiac arrest, hypotension/hypovolemia, severe coagulopathy, seizures, hemothorax/hemopericardium, uncontrolled bleeding. *Mechanical*: Circuit disruption, raceway rupture, system or component alarm/failure, air emboli, inadvertent decannulation, and clots.
Management of complex ECMO cases	Surgery on ECMO, post-operative bleeding, transport on ECMO (inter and intra-hospital).
Decannulation procedures	Personnel needed, medications required, potential complications, vessel ligation, vessel reconstruction, and percutaneous approach.
Post ECMO complications	Platelet and electrolyte alterations.
Short and long term developmental outcome of ECMO patients	Institutional follow-up protocol, literature review.

Table 7: ELSO Simulation Requirements for ECMO Specialists [9].

Water-drills	These sessions should be small enough so that each individual has hands-on experience. A full understanding of all possible circuit emergencies and the appropriate intervention should be accomplished by the end of this session. Each trainee should be able to describe and conceptually demonstrate how to change the major equipment (oxygenator, heat exchange, bladder) in a reasonable period of time. They should be able to change less complicated components of the circuit (raceway, pigtails, and checking pump head occlusion on ECMO) in a pre-established period of time.
Basic Session	Session should include a discussion and demonstration of the equipment including: Review of circuit configuration and function, access and sample ports to the circuit, basic circuit check, basic troubleshooting, pigtail and stopcock changes.
Emergency Session	Session should include training in the management of: raceway ruptures, heat exchanger, bladder, membrane lung changes (assist with procedure only) venous/arterial air, pump head occlusion checks, power failure, and inadvertent decannulation.
Animal Laboratory Sessions	As bedside training sessions are not possible in a new ECMO center, more extensive laboratory training is required compared to an experienced center. Sessions should include a review of the circuit and the access and sampling ports and the trainees should practice such tasks such as blood product administration, IV solution administration, medication administration and blood gas, ACT, and laboratory sampling. The use of documentation such as the flowsheet, physician and standing orders should be incorporated used during this session. Each specialist should be able to manage the patient on ECMO while the parameters (ACT, PaO2, and Post PCO2) are altered.

Table 8: ELSO ECMO Specialist Training Outline For Experienced Centers [9].

Didactic Sessions	Refer to Table 7 (for new ECMO centers)
Water-drills	Refer to Table 7 (for new ECMO centers)
Animal Sessions	Time in the animal lab is not required for experienced centers, but may be useful. If animals are not used, additional water-drill time can be added.
Bedside Training	The bedside training time of the new specialist should be between 16 and 32 hours in 8- 12-hour shifts. The preceptor should be an experienced specialist.

For institutions that do not educate their RNs to the ECMO specialist standards outlined in Tables 6,7, and 8, both the didactic content and length of classroom time is not standardized. However, when looking at the available literature, as well as ELSO centers of excellence who have similar models, there are some recommendations that can be made. The common didactic content recommended for initial ECMO training focuses on four sessions: an introduction to ECMO, patient monitoring and management, circuit monitoring and management, and emergency situations [4, 9, 25, 28]. These recommendations somewhat mirror the ELSO ECMO specialist education but allow for provision of the content in far less than the 24 to 36 hours required for the ECMO specialist. These recommendations are also in line with both the Basic Safety Course presented by Gannon *et al*. and with the education provided to RNs by other ELSO centers of excellence [9, 25, 28]. The specific contents of these four sessions are further outlined in Table 9.

Table 9: Recommendations for Didactic ECMO Education Content for the Bedside RN.

Session	Content
Introduction to ECMO	• The definition of ECMO • Physiology • Utilization and mortality • Indications and contraindications • Circuit components (institution specific) • Configurations (VA, VV, RVAD), and conditions treated with each configuration • Model of care and role responsibilities (institution specific)
Circuit Monitoring and Management	• Circuit components: pump, oxygenator, blender, monitors, flow probes, heat exchangers, cannulas and tubing, and institutional specifics • Monitoring parameters and causes of changes (institution specific) • The circuit check • Preload versus afterload complications and interventions (as seen on the circuit)
Patient Monitoring and Management	• Normal lab parameters on ECMO • Physiology: factors effecting O2 delivery and CO2 levels • Hemodynamics • Anticoagulation (institution specific) • Sedation and paralytics • Temperature management • Transfusions • Preload versus afterload complications and interventions (as seen in the patient) • Pulse checks and risk of ischemia
Emergency Situations	• When and how to perform CPR • Clamping • Hand cranking • When to notify a provider • Recirculation • Pneumothorax • Bedside/emergent cannulation

Duration of training is a consideration in any program. The necessary length of initial ECMO education is impacted by two factors: didactic content and hands-on time. To adequately cover the didactic material outlined in Table 9, there was some variability in the literature ranging from 1 to 6 hours [22, 25, 28]. The 1-hour didactic course presented by Gannon *et al*. did appear to contain adequate material; however, in an interview with the ECMO & Mechanical Circulatory Support Program Manager at NYU Langone Health, Bridget Toy, she indicated that under normal conditions, their initial ECMO education consists of a 4-hour long course [25, 28]. NYU Langone is an ELSO Gold Level Center of Excellence that utilizes RNs in a PCG model with either perfusionists or RNs in the ECMO specialist role who are always in house and round on patients at set intervals [28].

In another interview with Jennifer Guy, one of the ECMO Coordinators at Froedtert Hospital in Milwaukee, a similar duration of training was seen for their bedside RNs [3]. Froedtert Hospital is also an ELSO Gold Level Center of Excellence and they utilize a 6-hour course that is taught by a multidisciplinary team, covers topics in line with those outlined in Table 9, and includes hands-on time with the ECMO circuit and carts [29]. This center also includes 4 to 8 hours of ECMO shadowing and recently added bi-annual wet lab participation as a requirement for the bedside RNs [29]. Based on the input from multiple ELSO Gold Level Centers of Excellence, the literature, and the content recommended for the didactic content, the authors recommendation for length of the didactic session for initial training is 2 to 4 hours.

The inclusion and duration of a hands-on portion of initial education varies greatly due to the various models utilized. At centers that had ECMO specialists always

present in the ICU, no hands-on time was identified in the RN training plan [3]. In centers that used a PCG model with perfusion/ECMO specialist rounding, it appeared that centers provided a basic ECMO circuit walk through, and many paired this with low fidelity simulation lasting approximately 1 hour [4, 25, 28]. Based on these findings, it is a recommendation of this project that the focus of hands-on time should be to identify the components of the ECMO circuit, perform a circuit check, and demonstrate how to respond to emergency situations. A description of these recommendations for the hands-on portion of initial training can be found in Table 10. Based on the content outlined in Table 10, this author's recommended duration for hands-on time is 1 hour or more, with instructor-to-student ratios from 1:1 to 1:6 [25, 30]. The class size may warrant adjustment to this timeframe in order to ensure adequate exposure.

Table 10: Hands-on ECMO Training Topics for Nursing Education.

Identifying ECMO Circuit Components	• Pump • Oxygenator • Heater-cooler • Flow Probes • Monitors
Performing a Circuit Check	• Blood Color Change • Parameters, Trending, and Charting • Clots/Fibrin • Kinking • Connections
Responding to Emergency Situations	• Arterial Air • Venous Air • Power Loss • Decannulation (Arterial and Venous)

There are some additional aspects of initial ECMO education that are commonly reported in the literature. One commonality is a pre and post test for the didactic content, as well as a test-off for hands-on skills [4, 9, 19, 20, 22, 23, 25, 28, 29]. These were often developed at an institutional level utilizing a multidisciplinary team and the exact questions were not distributed; however, Gannon *et al*. published the pre and post test that was utilized for both their basic and advanced user course in their study [25]. A resource for course evaluation, as well as the tests for the basic and advanced user courses, can be found in Appendix B. Many institutions also require newly trained RNs to shadow a trained experienced RN who is caring for an ECMO patient following initial training [9, 25, 28, 29]. There was no set duration for shadowing identified in the literature; however, 4 to 8 hours of shadowing was recommended by both of the ELSO Gold Level Centers of Excellence interviewed [28, 29]. This author's recommendation is 4 to 8 hours of shadowing after ECMO training is completed in order to allow RNs to integrate their learning into a real life setting before providing care on their own. This recommendation should be adjusted based on the RN's comfort when appropriate. A summary of all initial education recommendations is shown in Figure 6.

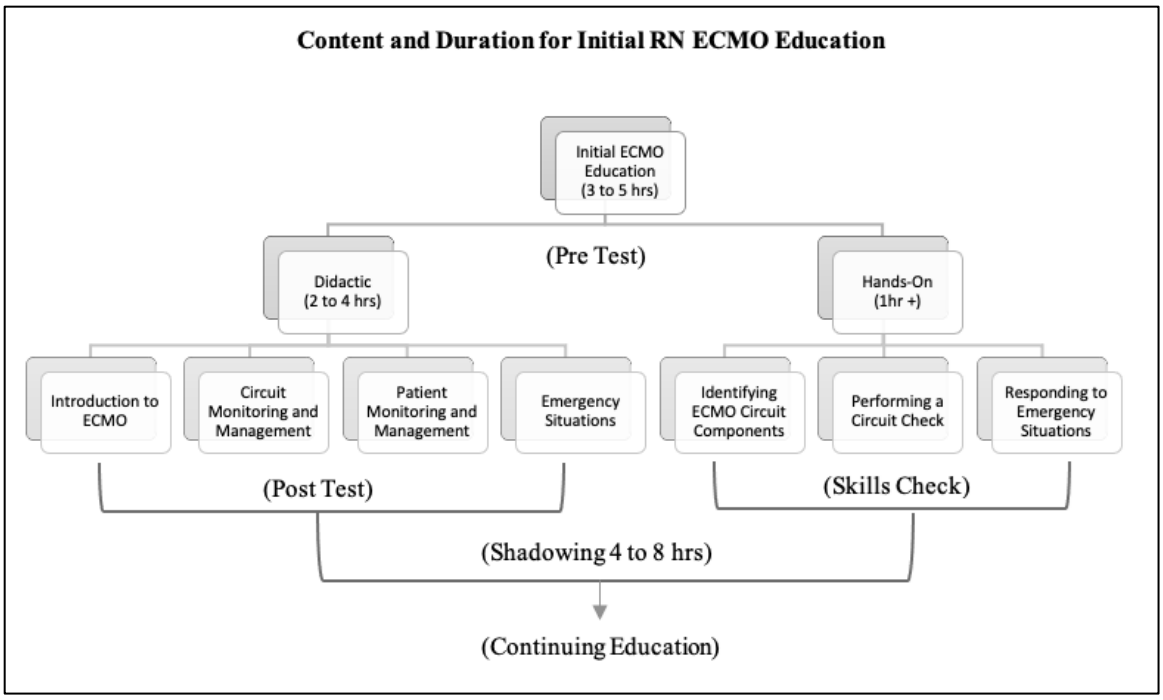

Figure 6: Summary of Content and Duration for Initial RN ECMO Education.

The recommendations for continuing education appeared consistent in the literature with a required 2-hour refresher course [25, 28]. The incorporation of wet labs and/or simulation should be considered as this was recommended by some centers and is also recommended by ELSO [9, 25, 29]. Since many of the RNs who take ECMO patients are also required to maintain competencies on other support devices such as durable ventricular assist devices (VAD), Impellas, and intra-aortic balloon pumps (IABP), the continuing education was consolidated into the same day to maximize training efficiency when appropriate [28].

4.4: Rapid Education

Every institution will have different timelines when initiating, or scaling, ECMO training programs. Because of this, rapid education may take on different meanings in different situations; however, in all circumstances, the recommendations associated with rapid education are meant to facilitate the training and integration of the greatest number of staff in the shortest period without sacrificing safety. The largest factor that can, and will in many cases, limit this kind of education is the number of staff who are qualified to participate in ECMO training. In a review of centers that utilized a rapid education model, existing ICU nurses were the main group who participated in training, which suggests that these hospitals possessed a pool of experienced staff who were not previously caring for ECMO [3, 7, 8, 15, 16, 25]. If an institution is already utilizing their experienced staff or has a lack of experienced staff and only inexperienced staff are available, there may be a lack of background knowledge in regard to hemodynamics, medications, and overall patient management that could limit the RN's ability to provide safe and effective care. There was one abstract found in the literature describing a single center's experience in rapidly educating nurses from all backgrounds in veno-venous ECMO (VV-ECMO) in response to the COVID-19 pandemic [4].

Under select emergency situations, rapid training has been used to increase the number of RNs who can care for ECMO patients. These instances include the COVID-19 and H1N1 pandemics. There are limited examples of this model, and due to the increase in utilization of ECMO since the 2009 H1N1 pandemic, the models seen in the literature were used very recently for COVID-19 response. Rapid education has its merits when used appropriately, and the limited literature does suggest that rapid education would be

suitable to meet the minimum education required to maintain safety in the setting of massive lack of staff or increase in ECMO volume. This level of RN education should be limited to those times when it is absolutely necessary and should not be utilized as a normal training model, at least not until adequate research is performed to support its efficacy.

The topics covered in rapid education courses include introduction to ECMO, circuit components, daily management, and emergency management as well as a walk through of the ECMO circuit and ECMO equipment cart [28]. The limitation of one specific study employed to make these recommendations is that the course utilized focused exclusively on VV-ECMO; however, the model of training resulted in no change in outcomes despite 61% of the ECMO care hours being provided by RNs who completed only the rapid education. The addition of Veno-Arterial (VA) ECMO education should be taken into consideration, but the rapid education model did result in adequate staffing and patient outcomes when utilized, which is the goal of rapid education. The topics covered in the rapid course are nearly identical to those recommended for initial education in Table 9, and the 2-hour duration is in line with the Basic Education course seen in Table 3, so the format of the class is supported by the literature. The RN's background and the lack of shadowing present the biggest obstacle to utilizing this model of training.

5.0: Discussion

There is currently no generally accepted standards for the initial ECMO education for RNs, which is not surprising based on the variety of ECMO care models that can be utilized. A review of available training programs did identify some commonalities which were used to develop recommendations that the author hopes are generalizable to any institution that uses RNs to provide bedside care for patients without a perfusionist, or other ECMO specialist, present at the bedside. These recommendations include both a standard training and an accelerated training plan, the latter of which would only be suitable during times of severe short staffing or a large increase in a center's ECMO volume.

Due to the lack of information in the literature on the topic of initial RN ECMO education, future studies utilizing the education models currently being utilized by additional ELSO centers of excellence would be beneficial. Focusing on institutions that have a recognized ECMO program that meets ELSO's current standards may provide insights into the development of another set of standards that applies to the education of the bedside RN. Since ELSO is currently the only certifying ECMO organization, they are also potentially the best group to standardize this kind of RN education in the future. Additionally, organizations such as the American Nursing Association, American Association of Critical-Care Nurses, the American Board of Nursing Specialists, and other international nursing associations could be excellent contributors for education recommendations. These organizations may also have the best platform to better define, establish, and advocate for the various RN roles which are associated with ECMO.

Additionally, these organizations have a unique ability to increase the awareness of such RN roles within the health care community, which could aid in their development as well as attract interest in the field.

Bedside resources are another tool in the realm of RN education that may be useful for improving patient safety, RN knowledge, and communication between disciplines. Future development of both standardized and institutional resources can be considered to enhance RN education and further support the bedside RN. Utilizing and tailoring these resources to fit a center's needs may be an especially effective way to support RNs during a time when a rapid training model is being utilized.

ECMO programs in the literature appeared to have similar education goals that focused on ensuring patient safety and improving patient outcomes. The training plans that hospitals utilized reflected these values in their education by placing a heavy emphasis on early identification of, and response to, emergencies. There were not any educational topics found in the literature that were necessarily excluded in this document; however, many articles did not specify the duration that was used to cover specific topics, and variability in the duration of teaching could potentially affect the depth of instruction provided to the bedside RN.

ECMO education in general was found to be relatively unique within the scope of RN education because it is often the most time-intensive training an RN can participate in within a hospital system. The training to care for patients supported by other devices is, in general, much shorter, which was verified by the ECMO coordinators at both NYU Langone and Froedtert Hospital [25, 29]. Because of this, the education models that these

courses utilize must be adapted in order to be applicable for ECMO training. The aspects that appeared to be transferrable are a focus on safety and emergency response.

To better understand the differences and similarities between ECMO education and other similar RN training models, it is useful to look at examples of education models for other high level devices that an RN would be trained for. One such device is the VAD, which is commonly cared for by an RN who participated in a training class before being allowed to care for patients supported by these devices. The main focus for this class is on safe patient management and identifying and responding to emergencies. This includes ensuring that the VAD is hooked up to the correct power sources, doing battery changes, doing controller change outs, and teaching the RN how to troubleshoot complications such as suction events. Additionally, performing sterile dressing changes is usually covered as it is another essential part of ensuring that patients stay safe and healthy. The main focus of patient safety in the VAD course is mirrored in the ECMO courses seen in the literature, and is also reflected in the recommendations presented in this document. The biggest difference between VAD training and ECMO training appears to be the level of understanding that the RN must possess in so many different aspects of patient care in order to provide safe care for the ECMO patient. VADs are undoubtedly a high level support device; however, they are not as intensive as caring for an ECMO patient. VAD patients can be trained to perform their own monitoring and care and can then leave the hospital with the device. The difference between managing these high-level devices is difficult to quantify, but it can safely be said that the RN education needed for the management of ECMO is not equivalent to that of any other therapy or

device because of the all-encompassing nature of the support being provided and the risk of patient harm if the RN does not possess adequate understanding.

The use of video training was one of the topics that appeared several times within the interviews conducted for this project. Video training was incorporated into some of the third party ECMO courses identified in Section 4.1, but it was not found to be commonly utilized at an institutional level for either initial or rapid training, most likely due to the need for hands-on time in conjunction with such training [19, 21, 22, 28, 29, 31]. In the future, studies about the efficacy of video, virtual reality, or other electronic delivery resources will be needed; however, video and other electronic methods of training do appear to be an area of great interest at the current time and could aid in the standardization of ECMO education and education of large groups of RNs without placing a large demand on the interdisciplinary ECMO education team.

5.1: Conclusion

The utilization of ECMO has seen tremendous growth that has required significant adaptation within the health care field [1]. Education of the entire multidisciplinary team is vital to providing high level care and improving patient outcomes. The bedside RN falls into a unique role that does not have any standardized education requirements despite the fact that RNs are present at the bedside at all times for this patient population [26, 27]. Nursing as a profession has been recognized as a suitable background to allow RNs to move into the ECMO specialist role by obtaining additional education; however, most RNs do not function in this role, and hospitals may choose management models that do not utilize RNs in this way [9]. After reviewing the

literature, conducting interviews, and looking at the various training models and standards, this education gap for RNs who care for ECMO patients but are not in an ECMO specialist role became apparent. The recommendations for initial education of RNs outlined in Figure 6 were compiled utilizing topics consistently seen in the literature, and the utilization of these topics was verified during interviews with ECMO Coordinators at ELSO Gold Level Centers of Excellence [25, 28, 29].

The utilization of rapid education models had limited support in the literature, but the acute need for ECMO trained RNs seen during the COVID-19 pandemic forced some form of rapid education on each ELSO center interviewed, indicating that there is opportunity for a rapid training model [28, 29]. The recommendations for the rapid model outlined in Section 4.4 are similar in didactic content to recommendations presented in Table 9 for the initial ECMO education for any RN. The largest areas of modification for this model were made to hands-on time, shadowing requirements, and the background requirements for RNs participating in training. These modifications to initial education were utilized to both shorten the duration of training and increase the pool of RNs available to care for ECMO patients. This style of rapid education appeared to be a valid option in the presence of massive staff shortage but did not have substantial data to support its long term efficacy. Education of the RN caring for ECMO patients is necessary to maintain patient safety, and as such, the bedside RN deserves adequate education to support their provision of care to ECMO patients.

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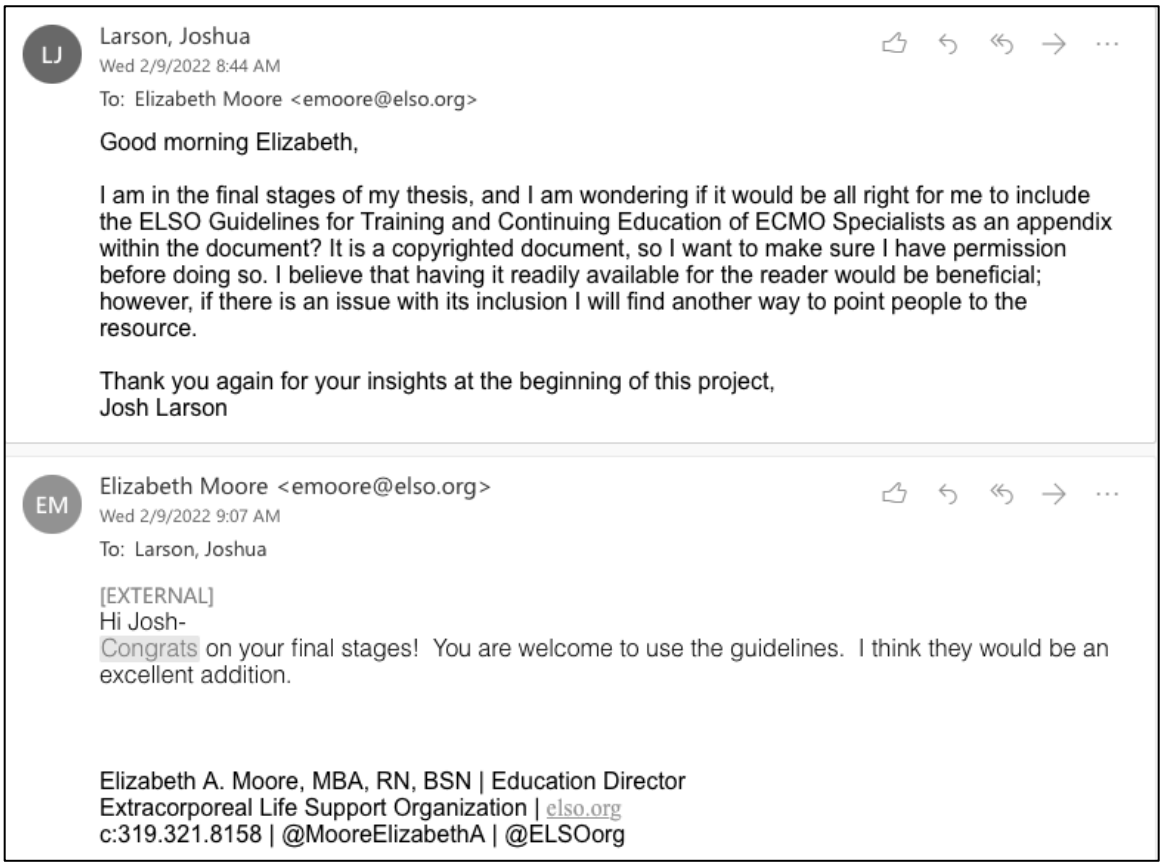
Appendix A: ELSO Guidelines for Training and Continuing Education of ECMO Specialists



LJ

Larson, Joshua
Wed 2/9/2022 8:44 AM

To: Elizabeth Moore <emoore@elso.org>

Good morning Elizabeth,

I am in the final stages of my thesis, and I am wondering if it would be all right for me to include the ELSO Guidelines for Training and Continuing Education of ECMO Specialists as an appendix within the document? It is a copyrighted document, so I want to make sure I have permission before doing so. I believe that having it readily available for the reader would be beneficial; however, if there is an issue with its inclusion I will find another way to point people to the resource.

Thank you again for your insights at the beginning of this project,
Josh Larson

EM

Elizabeth Moore <emoore@elso.org>
Wed 2/9/2022 9:07 AM

To: Larson, Joshua

[EXTERNAL]
Hi Josh-
Congrats on your final stages! You are welcome to use the guidelines. I think they would be an excellent addition.

Elizabeth A. Moore, MBA, RN, BSN | Education Director
Extracorporeal Life Support Organization | elso.org
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Figure A-1: Permission to Include Copyrighted Material

ELSO GUIDELINES FOR TRAINING AND CONTINUING EDUCATION OF ECMO SPECIALISTS

PURPOSE

The "*ELSO Guidelines for Training and Continuing Education of ECMO Specialists*" is a document developed by the Extracorporeal Life Support Organization (ELSO) as a reference for current and future ECMO centers. It is to be used as a guideline for designing training and education programs for ECMO specialists. It is assumed that each ECMO center must develop their institution specific guidelines and policies for training ECMO Specialists, which may vary. In the development of these documents and programs, ECMO Directors and Coordinators must take into account their institution's requirements for in-house training programs, and must have policies and procedures reviewed by appropriate hospital committees. Please note that institutional and personnel requirements for ECMO programs are addressed in the ELSO document, "*Guidelines for ECMO Centers*", and will not be discussed in this document.

INTRODUCTION

The term "ECMO Specialist" is defined for the purpose of these guidelines as "the technical specialist trained to manage the ECMO system and the clinical needs of the patient on ECMO under the direction and supervision of a licensed ECMO trained physician. The individual functioning as the ECMO Specialist should have a strong critical care background in neonatal, pediatric and/or adult critical care and have attained one of the following:

1. Successful completion of an approved school of nursing and achievement of a passing score on the state written exam given by the Board of Nursing for that state;

2. Successful completion of an accredited school of respiratory therapy and have successfully completed the registry examination for advanced level practitioners and be recognized as a Registered Respiratory Therapist (RRT) by the National Board of Respiratory Care (NBRC).

3. Successful completion of an accredited school of perfusion and national certification through the American Board of Cardiovascular Perfusion (ABCP).

4. Physicians trained in ECMO who have successfully completed institutional training requirements for the clinical specialists.

5. Other medical personnel such as biomedical engineers or technicians who received specific ECMO training and have practiced as an ECMO specialist since the initiation of their programs, and who have completed equivalent training in ECMO management as the other specialists, have successfully documented necessary skills as an ECMO specialist, and who have been approved specifically as an ECMO specialist by the medical director. These personnel can be approved institutionally as an ECMO specialist under the “grandfather” principle. However ELSO does not encourage or support the new training of individuals except as outlined in 1-4 above.

TRAINING

Training of the ECMO will be divided into two parts. Training for new ECMO programs (centers which have not treated patients) will be covered separately from training for experienced ECMO programs (centers which have been in ongoing operation and are training new ECMO specialists).

TRAINING OUTLINE: NEW ECMO PROGRAM

A. **Didactic Course**: The didactic course should include, but not be limited to the following topics. Between 24 to 36 hours will be required to cover the following material. Case presentations are encouraged.

Topics could include, but are not limited to the following:

- ***Introduction to ECMO***:
  History
  Current status
  Indications
  Risks and benefits
  Membrane gas exchange physics and physiology
  Oxygen content, delivery and consumption
  Shunt physiology
  Types of ECMO
  Future applications
  Research

- ***Physiology of the diseases treated with ECMO***:
  Persistent Pulmonary Hypertension
  Meconium Aspiration Syndrome
  Respiratory Distress Syndrome
  Congenital Diaphragmatic Hernia
  Sepsis/pneumonia
  Post-operative congenital heart disease/heart transplantation
  Cardiomyopathy/myocarditis
  ARDS
  Aspiration pneumonia
  Pulmonary embolism

- ***Pre ECMO Procedures:***
  Notification of the ECMO Team
  Cannulation procedure
    -open
    -percutaneous
  Initiation of bypass
  Responsibility of team members

- ***Criteria and contraindications for ECMO including***:
  Patient Selection
  Selection criteria
  Pre-ECMO evaluation

- ***Physiology of coagulation including***:
  Coagulation cascade
  Activated clotting times (ACT's)
  Disseminated intravascular coagulation
  Blood products and interactions
  Blood product management of the bleeding patient
  Blood surface interactions
  Laboratory tests
  Heparin pharmacology
  Use of Amicar, Protamine and other drugs

- ***ECMO equipment including***:
  Circuit priming
  Oxygenator function and blood gas control
  ECMO circuit design
  ECMO circuit components (cannula, pump, venous return monitor, in-line saturation monitor, pressure monitor, heater, hemofilter, bubble detector)

- ***Physiology of Venoarterial and Venovenous ECMO***:
  Indications
  Physiology
  Advantages/disadvantages

- ***Daily Patient and Circuit management on ECMO including:***
  Patient:
    Fluid, electrolytes and nutrition
    Respiratory
    Neurologic
    Infection control
    Sedation and pain control
    Hematology
    Cardiac
    Psychosocial

  Circuit:
    Aseptic technique
    Pump/gas flow
    Pressure monitoring
    Blood product infusion techniques
    Circuit infusions
    Management of anticoagulation
    Circuit checks
    Hemofiltrations set-up
    Bedside care of the ECMO patient

- ***Emergencies and complications during ECMO***:
  Medical:
    Intracranial and other hemorrhage
    Pneumothorax/pneumopericardium
    Cardiac Arrest
    Hypotension/hypovolemia
    Severe coagulopathy
    Seizures
    Hemothorax/hemopericardium
    Uncontrolled bleeding

  Mechanical:
    Circuit disruption
    Raceway rupture
    System or component alarm/failure (pump, bladder, venous return monitor, oxygenator, heater)
    Air embolus
    Inadvertent decannulation
    Clots

- ***Management of complex ECMO cases***:
  Surgery on ECMO
    -post-operative bleeding
  Transport on ECMO (inter and intra-hospital)

- ***Weaning from ECMO (techniques and complications):***
  Clinical indications of pulmonary/cardiac recovery
  Pump/gas flow weaning techniques
  ACT changes during weaning
  Ventilatory changes during weaning
  Trial off/decannulation from low flow

- ***Decannulation procedures***:
  Personnel needed
  Medications required
  Potential complications
  Vessel ligation
  Vessel reconstruction
  Percutaneous approach

- ***Post ECMO complications***:
  Platelet and electrolyte alterations

- ***Short and long-term developmental outcome of ECMO patients***:
  Institutional follow-up protocol
  Literature review

- ***Ethical and social issues***:
  Consent process
  Parental and family support

Withdrawal of ECMO support

B. **Water-drills**: These sessions should be small enough so that each individual has hands-on experience. A full understanding of all possible circuit emergencies and the appropriate intervention should be accomplished by the end of this session. Each trainee should be able to describe and conceptually demonstrate how to change the major equipment (oxygenator, heat exchange, bladder) in a reasonable period of time. They should be able to change less complicated components of the circuit (raceway, pigtails, and checking pump head occlusion on ECMO) in a pre-established period of time.

- ***Basic Session should include*** *a discussion and demonstration of the equipment including*:
  Review of Circuit configuration and function
  Access and sample ports to the circuit
  "The basic circuit check'
  Basic troubleshooting
  Pigtail and stopcock changes

- ***Emergency Session, should include*** *training in the management of:*
  Raceway ruptures
  Heat exchanger, bladder, membrane lung changes (assist with procedure only)
  Venous/arterial air
  Pump head occlusion checks
  Power failure
  Inadvertent decannulation

C. **Animal Laboratory Sessions:** As bedside training sessions are not possible in a new ECMO center, more extensive laboratory training is required compared to an experienced center.

- The species of animal and the duration of the ECMO training run will vary depending on the institution's ability to supply long-term support of animals during these sessions. ECMO centers typically have used newborn lambs, adult sheep or piglets. It is recommended that animal labs be conducted for a continuing 24-72 hour period to decrease the number of animals needed for

these sessions and to simulate around the clock management of the ECMO system.

- Trainees should be divided into small teams with the instructor for four to eight hour sessions.

- Sessions should include a review of the circuit and the access and sampling ports and the trainees should practice such tasks such as blood product administration, IV solution administration, medication administration and blood gas, ACT, and laboratory sampling. The use of documentation such as the flowsheet, physician and standing orders should be incorporated used during this session.

- Each specialist should be able to manage the patient on ECMO while the parameters (ACT, PaO2, and Post PCO2) are altered. It is recommended that this session should last 8-12 hours.

- A session, lasting 4-8 hours, should focus on emergencies including:
  Cracked pigtails and connectors
  Leaking stopcocks
  Raceway rupture
  Membrane oxygenator failure
  Air in the circuit
  Loss of venous return
  Inadvertent decannulation
  Pump stop scenarios and handcranking
  Power failure

- For new centers these sessions should be repeated until all team members gain a solid understanding of the management of the ECMO system and are fully competent managing simulated ECMO emergencies. After initial sessions, most centers require one - two additional eight-hour sessions per specialist.

EXPERIENCED CENTER: TRAINING OUTLINE

A. **Didactic Sessions** - as above

B. **Water-drills** - as above

C. **Animal Sessions:** Time in the animal lab is not required for experienced centers, but may be useful. If animals are not used, additional water drill time can be added.

D. **Bedside Training:** The bedside training time of the new Specialist should be between 16 and 32 hours in 8 or 12-hour shifts. The preceptor should be an experienced specialist.

EVALUATION AND INSTITUTIONAL CERTIFICATION OF THE ECMO SPECIALISTS

A. **Written Evaluation**: Each specialist should have on record a written evaluation of their skills and competence during all sessions of the ECMO training course including; course attendance, water-drills, animal lab sessions and examinations.

B. **Written/Oral Exam**: Written exam, with pre-determined passing level, covering didactic and laboratory sessions should be taken by all Specialists.

C. **Institutional Certification**: Institutional certification of Specialists will be granted after successful completion of the ECMO training course (didactic, water drills/animal labs, bedside training) and successfully passing the oral and/or written exam.

CONTINUING EDUCATION OF THE ECMO SPECIALIST

A. **Formal team meetings, which include:**
Case reviews
Updates on ECMO therapy
Quality assurance
Review of ECMO policy and procedures
Administrative information

- Frequency of meetings should be based on the size of the team and the volume of ECMO patients treated.
- Attendance records should be monitored and team members should be required to attend a certain number of meetings as specified by the particular ECMO center.

B. **Water-drills:** Water drills should be held periodically throughout the year as specified by the particular ECMO center (every six months is recommended as a minimum). The exact interval should be based on volume of ECMO patients treated in the ECMO center.

C. **Annual examination**: This is recommended to verify the knowledge and skills of all specialists. Ongoing evaluation of performance should also be conducted and reviewed with the Specialist.

D. **Minimum number of hours of pump time**: Each center should set a minimum amount of pump time for the specialist to maintain competency. For example, a center might specify that each Specialist performs at least one 8-hour clinical shift every eight weeks in order to maintain certification. Re-training should be undertaken if this standard is not met.

Appendix B: ECMO Course Tests and Course Evaluation

Thank you for helping us evaluate and understand how to improve our ECMO curriculum for nurses moving forward. We appreciate your feedback and your time.

Please answer each question below using the rating scale from "strongly disagree" to "strongly agree."

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. The ECMO nursing courses/modules have increased my understanding of ECMO.	☐	☐	☐	☐	☐
2. The ECMO nursing courses/modules have increased my confidence in providing nursing care to ECMO patients.	☐	☐	☐	☐	☐
3. The ECMO nursing courses/modules have been applicable to caring for ECMO patients.	☐	☐	☐	☐	☐
4. The ECMO nursing courses/modules have increased my ability to safely care for ECMO patients.	☐	☐	☐	☐	☐
5. I refer to the knowledge and skills I've learned during the ECMO nursing courses when I care for my ECMO patients.	☐	☐	☐	☐	☐
6. Quality of nursing care for ECMO patients is improved by the ECMO courses/modules for nurses.	☐	☐	☐	☐	☐
7. I would recommend these nursing courses/modules to other nurses new to ECMO.	☐	☐	☐	☐	☐

Figure B-1: Example of Curriculum Evaluation for ECMO Courses.[1]

[1]Gannon, W. D., Craig, L., Netzel, L., Mauldin, C., Troutt, A., Warhoover, M., Tipograf, Y., Hogrefe, K., Rice, T. W., Shah, A., & Bacchetta, M. (2020). Curriculum to Introduce critical care nurses to extracorporeal membrane oxygenation. *American Journal of Critical Care*, *29*(4), 262–269. https://doi.org/10.4037/ajcc2020739

1) During VA-ECMO:
   a. Blood is drained from the venous system and returned to the venous system
   b. Blood is drained from the venous system and returned to the arterial system

2) VA-ECMO supports which of the following?
   a. Circulatory system
   b. Oxygenation/CO_2 removal
   c. Blood pressure
   d. Cardiac and cardiopulmonary system

3) During VV-ECMO:
   a. Blood is drained from the venous system and returned to the venous system
   b. Blood is drained from the venous system and returned to the arterial system

4) VV-ECMO supports which of the following:
   a. Oxygenation/CO_2 removal
   b. Blood pressure
   c. Cardiac and cardiopulmonary system
   d. All of the above

5) Increasing the blood flow rate on VV-ECMO will most likely:
   a. Improve CO_2 removal
   b. Improve Pao_2
   c. Improve hemodynamics
   d. All of the above

6) Your patient has a decreasing blood pressure; you notice your ECMO flows have drifted down over the past few hours by 0.5 LPM. A member of the health care team who is approved to titrate flows on the pump comes by and increases the flow and you see a corresponding rise in your patient's blood pressure. Which type of ECMO is your patient receiving?
   a. VV-ECMO
   b. VA-ECMO

7) Select the correct statement from the choices below regarding sweep.
   a. Higher sweep flow removes less CO_2
   b. Higher sweep adds more O_2
   c. Higher sweep removes more CO_2
   d. Higher sweep increases circulatory support

8) Your VV-ECMO patient is showing signs of hypoxia (Spo_2 decreasing from baseline, Pao_2 decreasing). You notice that both the drain and return line of ECMO circuit are the same dark-colored blood. What is happening?
   a. Gas/ECMO pump Failure
   b. Patient recovery
   c. Mechanical ventilation failure

9) Is the above scenario in question 8 an emergency? What should you do?
   a. No/no action required
   b. Yes/assess cannulation sites
   c. Yes/clamp ECMO lines and STAT call perfusion
   d. Yes/transition to O_2 tank and STAT call perfusion

10) T/F: A patient with a femoral cannula receiving VV-ECMO patient should never get out of bed.
   a. True
   b. False

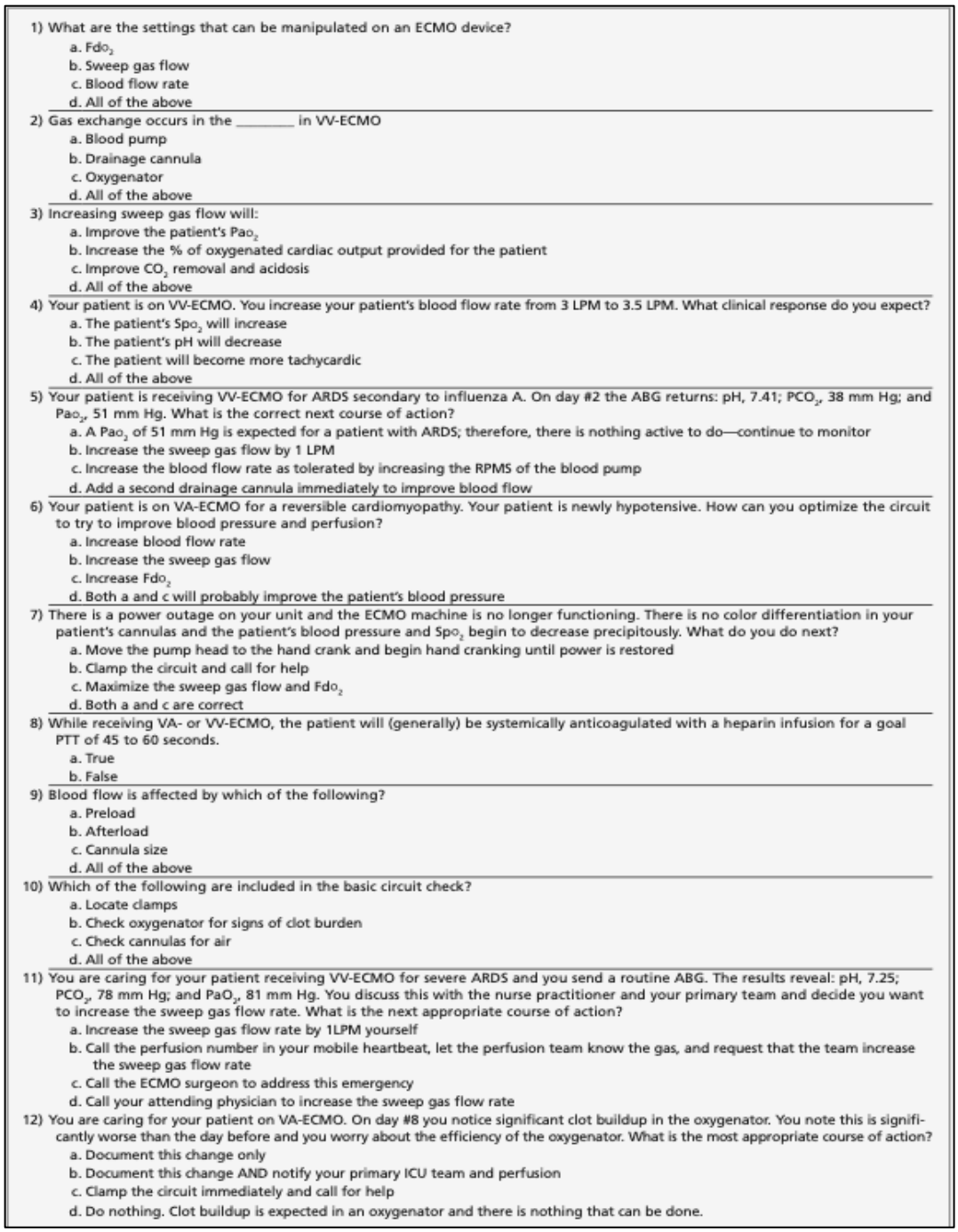
11) Your patient is on VA-ECMO. You get in report that their sweep value has been at 0.9 LPM x 48h, Fdo_2 is 60%, and their blood flow has ranged from 3.77 to 4.01 LPM over the previous shift. As you begin your circuit checklist assessment, you notice your patient's hemodynamics are stable and their blood flow is 3.83 LPM. As you continue your circuit checklist, you assess the Fdo_2 and sweep flow rate, you notice the sweep has been turned off. What should happen next?
   a. Nothing. The patient is probably on a weaning trial
   b. Should be recognized as an emergency—immediately turn sweep on to 1 LPM, call perfusion, STAT, notify your team
   c. Wait for daily rounds to address the issue

12) The following are indications for ECMO:
   a. Reversible heart failure
   b. Bridge to heart or lung transplant
   c. Pulmonary hypertensive crisis
   d. Active hemorrhage
   e. a, b, c

13) Patients on ECMO should not be anticoagulated.
   a. True
   b. False

Figure B-2: Examination Given Before and After Basic Safety Course.[1] (Abbreviations: CO_2, carbon dioxide; FdO_2, fraction of delivered oxygen; ECMO, extracorporeal membrane oxygenation; LPM, liters per minute; O_2, oxygen; Spo_2, oxygen saturation as shown by pulse oximetry; STAT, urgently; VA, venoarterial; VV, venovenous)

[1]Gannon, W. D., Craig, L., Netzel, L., Mauldin, C., Troutt, A., Warhoover, M., Tipograf, Y., Hogrefe, K., Rice, T. W., Shah, A., & Bacchetta, M. (2020). Curriculum to Introduce critical care nurses to extracorporeal membrane oxygenation. *American Journal of Critical Care*, *29*(4), 262–269. https://doi.org/10.4037/ajcc2020739



1) What are the settings that can be manipulated on an ECMO device?
   a. Fdo_2
   b. Sweep gas flow
   c. Blood flow rate
   d. All of the above

2) Gas exchange occurs in the _____ in VV-ECMO
   a. Blood pump
   b. Drainage cannula
   c. Oxygenator
   d. All of the above

3) Increasing sweep gas flow will:
   a. Improve the patient's Pao_2
   b. Increase the % of oxygenated cardiac output provided for the patient
   c. Improve CO_2 removal and acidosis
   d. All of the above

4) Your patient is on VV-ECMO. You increase your patient's blood flow rate from 3 LPM to 3.5 LPM. What clinical response do you expect?
   a. The patient's Spo_2 will increase
   b. The patient's pH will decrease
   c. The patient will become more tachycardic
   d. All of the above

5) Your patient is receiving VV-ECMO for ARDS secondary to influenza A. On day #2 the ABG returns: pH, 7.41; PCO_2, 38 mm Hg; and Pao_2, 51 mm Hg. What is the correct next course of action?
   a. A Pao_2 of 51 mm Hg is expected for a patient with ARDS; therefore, there is nothing active to do—continue to monitor
   b. Increase the sweep gas flow by 1 LPM
   c. Increase the blood flow rate as tolerated by increasing the RPMS of the blood pump
   d. Add a second drainage cannula immediately to improve blood flow

6) Your patient is on VA-ECMO for a reversible cardiomyopathy. Your patient is newly hypotensive. How can you optimize the circuit to try to improve blood pressure and perfusion?
   a. Increase blood flow rate
   b. Increase the sweep gas flow
   c. Increase Fdo_2
   d. Both a and c will probably improve the patient's blood pressure

7) There is a power outage on your unit and the ECMO machine is no longer functioning. There is no color differentiation in your patient's cannulas and the patient's blood pressure and Spo_2 begin to decrease precipitously. What do you do next?
   a. Move the pump head to the hand crank and begin hand cranking until power is restored
   b. Clamp the circuit and call for help
   c. Maximize the sweep gas flow and Fdo_2
   d. Both a and c are correct

8) While receiving VA- or VV-ECMO, the patient will (generally) be systemically anticoagulated with a heparin infusion for a goal PTT of 45 to 60 seconds.
   a. True
   b. False

9) Blood flow is affected by which of the following?
   a. Preload
   b. Afterload
   c. Cannula size
   d. All of the above

10) Which of the following are included in the basic circuit check?
   a. Locate clamps
   b. Check oxygenator for signs of clot burden
   c. Check cannulas for air
   d. All of the above

11) You are caring for your patient receiving VV-ECMO for severe ARDS and you send a routine ABG. The results reveal: pH, 7.25; PCO_2, 78 mm Hg; and PaO_2, 81 mm Hg. You discuss this with the nurse practitioner and your primary team and decide you want to increase the sweep gas flow rate. What is the next appropriate course of action?
   a. Increase the sweep gas flow rate by 1LPM yourself
   b. Call the perfusion number in your mobile heartbeat, let the perfusion team know the gas, and request that the team increase the sweep gas flow rate
   c. Call the ECMO surgeon to address this emergency
   d. Call your attending physician to increase the sweep gas flow rate

12) You are caring for your patient on VA-ECMO. On day #8 you notice significant clot buildup in the oxygenator. You note this is significantly worse than the day before and you worry about the efficiency of the oxygenator. What is the most appropriate course of action?
   a. Document this change only
   b. Document this change AND notify your primary ICU team and perfusion
   c. Clamp the circuit immediately and call for help
   d. Do nothing. Clot buildup is expected in an oxygenator and there is nothing that can be done.

Figure B-3: Examination Given Before and After Advanced Safety Course.[1] (Abbreviations: CO_2, carbon dioxide; Fdo_2, fraction of delivered oxygen; ECMO, extracorporeal membrane oxygenation; LPM, liters per minute; O_2, oxygen; Spo_2, oxygen saturation as shown by pulse oximetry; STAT, urgently; VA, venoarterial; VV, venovenous.

[1]Gannon, W. D., Craig, L., Netzel, L., Mauldin, C., Troutt, A., Warhoover, M., Tipograf, Y., Hogrefe, K., Rice, T. W., Shah, A., & Bacchetta, M. (2020). Curriculum to Introduce critical care nurses to extracorporeal membrane oxygenation. *American Journal of Critical Care*, *29*(4), 262–269. https://doi.org/10.4037/ajcc2020739

Thesis Approval Form

Master of Science in Perfusion -- MSP

Milwaukee School of Engineering

This thesis, titled "Education for Nursing Staff Caring for Extracorporeal Life Support Patients**,"** submitted by the student Joshua Larson, has been approved by the following committee:

Faculty Chairperson: _ Ron Gerrits _____ Date: __2/24/2022_____

Dr. Ron Gerrits, Ph.D.

Faculty Member: __Nicholas LaRue____ Date: _2/24/2022_____

Nick LaRue MS, CCP, LP

Faculty Member: _  ___Date: _2/24/2022_____

Gary Shimek, MLIS