

Recommendations From the Professional Advisory Committee on Nursing Practice in the Care of ECMO-Supported Patients

Semyon Melnikov, PhD, RN
Alex Furmanov, MSc, RN
Alik Gololobov, MA, RN
Muhammad Atrash, MA, RN
Chaya Broyer, MA, RN
Marta Gelkop, MA, RN
Slava Gezunterman, MA, RN
Tova David, MA, RN
Limor Eisenberg, MA, RN

Esam Kadry, MA, RN
Ruti Nave, MA, RN
Edna Shalom, MA, RN
Noga Shoval, MA, RN
Gregory Traytel, MA, RN
Nagah Zaid, MA, RN
Shoshy Goldberg, PhD, RN
Amir Vardi, MD

BACKGROUND By July 2020, the Extracorporeal Life Support Organization had documented more than 133 000 extracorporeal membrane oxygenation (ECMO) implementations, with more than 61 000 implementations in adult patients. No clear policies regarding the authority and responsibility of nursing staff in the treatment of ECMO-supported patients are currently available.

OBJECTIVE To formulate evidence-based recommendations for nursing care of ECMO-supported patients.

METHODS The National Head Nurse's office and the Professional Guidelines Department in the Nursing Division of Israel's Ministry of Health formed the Professional Advisory Committee on Nursing Practice in the Care of ECMO-Supported Patients to address concerns regarding the current state of professional nursing practice in the care of these patients. The Professional Advisory Committee brought together 15 senior Israeli ECMO nursing experts who explored the potential of registered nurses in caring for ECMO-supported patients, considered the competencies of nurses treating ECMO-supported patients, discussed training programs and health care policy, and examined nursing outcomes for quality assurance.

RESULTS The Professional Advisory Committee formulated recommendations regarding the following priority issues: (1) determining boundaries of professional authority and nurses' responsibilities, including designated activities for different professional ranks of registered nurses; (2) providing appropriate content for the training programs offered, such as generic/basic, above-basic, and clinical specialization nursing programs; and (3) defining relevant quality measures for nursing treatment of ECMO-supported patients.

CONCLUSIONS Introducing international standards would ensure the safety and effectiveness of nursing care for ECMO-supported patients through quality and risk management and establishment of new evidence-based nursing practices. (*Critical Care Nurse*. 2021;41[3]:e1-e8)

Extracorporeal membrane oxygenation (ECMO) provides support, for periods of days to weeks, to patients with respiratory failure, cardiac failure, or both.¹ The Extracorporeal Life Support Organization (ELSO), an international nonprofit consortium of health care institutions, maintains a registry of ECMO use around the world. From 1990 to July 2020, ELSO documented more than 133 000 ECMO implementations,

Authors

Semyon Melnikov is a senior lecturer in the Department of Nursing, Steyer School of Health Professions, Sackler Faculty of Medicine, Tel Aviv University, Israel.

Alex Furmanov is a head nurse of neuro and cardiothoracic surgery intensive care units (ICUs) at Hadassah Medical Center, Ein Kerem, Jerusalem, Israel.

Alik Gololobov is a coordinator of nursing professional development and standards at Assuta Medical Center, Tel Aviv.

Muhammad Atrash is a head nurse of the ICU at Baruch Padeh Medical Center, Poriya, Israel.

Chaya Broyer is a head nurse of the ICU at Shaare Zedek Medical Center, Jerusalem.

Marta Gelkop is a head nurse of the Cardiothoracic Surgery Department at Rabin Medical Center, Petah Tikva, Israel.

Slava Gezunterman is an ECMO coordinator in the cardiac surgery ICU at Sheba Medical Center, Ramat Gan, Israel.

Tova David is a coordinator, Professional Guidelines and Standards Department, Nursing Division, Ministry of Health, Israel.

Limor Eisenberg is a head of the Professional Guidelines and Standards Department, Nursing Division, Ministry of Health.

Esam Kadry is a head nurse of the heart surgery ICU at Rambam Medical Center, Haifa, Israel.

Ruti Nave is a registered nurse in the ICU at Tel Aviv Sourasky Medical Center, Tel Aviv, Israel.

Edna Shalom is a head nurse of the cardiothoracic surgery ICU at Sheba Medical Center.

Noga Shoval is a lecturer and clinical coordinator at The Yezreel Valley Academic College of Emek Yezreel, Israel.

Gregory Traytel is a deputy head nurse of the Cardiothoracic Surgery Department at Rabin Medical Center.

Nagah Zaid is a head nurse of the pediatric cardiac ICU and pediatric cardiac catheterization unit at Sheba Medical Center.

Shoshy Goldberg is the National Head Nurse of Israel and the Director of the Nursing Department at Ministry of Health.

Amir Vardi is the Head of the pediatric cardiac ICU and the Director of ECMO service at the Edmond and Lily Safra Children's hospital, Sheba Medical Center.

Corresponding author: Semyon Melnikov, PhD, RN, Department of Nursing, Steyer School of Health Professions, Sackler Faculty of Medicine, Tel Aviv University, Ramat Aviv, Tel Aviv 6997801, Israel (email: melniko@tauex.tau.ac.il).

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with more than 61 000 implementations in adult patients.² Adult ECMO cases increased by 433% from 2006 to 2011 in the United States,³ with corresponding increases in expenditure and resource use.⁴ Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2, is a health threat that by January 23, 2021, has led to more than 98 million confirmed cases and more than 2.1 million deaths globally.⁵ Approximately 15% to 30% of patients infected with COVID-19 develop acute respiratory distress syndrome.⁶ The World Health Organization guidelines for the management of suspected COVID-19 recommend initiating venovenous ECMO for eligible patients with COVID-19–related acute respiratory distress syndrome.⁷

To date, no clear policies regarding the authority and responsibility of nursing staff treating ECMO-supported patients (ECMO-SPs) have been published in scientific literature from around the world or among the procedures or guidelines issued by health ministries in different countries. Therefore, the office of the National Head Nurse and the Professional Guidelines Department in the Nursing Division of the Israeli Ministry of Health established a Professional Advisory Committee to provide recommendations that will become legal guidelines within Israel.

Traditionally, ECMO treatment is performed by a multidisciplinary team that includes “some combination of physicians, surgeons, transport specialists, nurses, perfusionists, or other ECMO specialists.”⁸ The patient’s needs are addressed by joint action in which team members act according to their ability to help the patient at any given moment. However, it is vitally important that every procedure be performed according to the standards of practice of each profession. In ECMO, interdisciplinary work is so critical that training courses are shared among physicians, registered nurses (RNs), and perfusionists.

Nursing Care of ECMO-SPs

In recent years, the growth in ECMO use has led to the integration and increased involvement of nursing staff in treating ECMO-SPs. Frequently, the care of an ECMO-SP involves not only nursing care but also the use of an ECMO device in both routine and emergency situations. A search of scientific literature published by official bodies, such as ministries of health, for a description of the responsibilities of various medical ECMO professionals (physicians, RNs, and perfusionists) in treating ECMO-SPs revealed a scarcity of material. The

New Zealand Ministry of Health, which developed a service model for ECMO, published guidelines for treating ECMO-SPs.⁹ However, no specific guidelines for RNs were included in their service model.

To our knowledge, this article is the first to emphasize the role and responsibilities of RNs in treating ECMO-SPs. Involving RNs in treating ECMO-SPs requires formulating clear policies regarding the authority and responsibility of the nursing staff, establishing professional standards and quality measures, defining educational content to be provided by the relevant training institutions, and continuously monitoring compliance with quality standards.

Division of Responsibility Between RNs and Perfusionists

In general, perfusionists and RNs can work with ECMO-SPs only if they have completed an ECMO course, currently provided in Israel by specific hospitals. Nursing and perfusion professionals have unique advantages when treating ECMO-SPs. Perfusionists have excellent knowledge of human anatomy and physiology, technical experience with and in-depth understanding of ECMO device technology, and awareness of the device flow behavior. Registered nurses understand the patient's physiological and pathophysiological state and the implications of changes in the patient's condition. Registered nurses also understand the technical problems that may befall the ECMO device. In addition, RNs have the advantage of being able to respond appropriately in emergency situations, whereas perfusionists are not licensed to assist patients in emergencies. Currently, the scope of practice and division of responsibilities between nurses and perfusionists are determined by the management of each hospital and therefore can vary among hospitals. Some hospitals have readily available perfusionists who can do a large part of the work. Other hospitals have no perfusionists at all, and when these hospitals take care of ECMO-SPs, nurses do most of the work. In these cases, perfusionists are available only in emergency situations. Availability must be kept in mind, and although medical centers differ, most have more RNs than perfusionists.

The multifaceted capabilities of RNs are illustrated by protocols for nurses in intensive care in general and ECMO care in particular. In both cases, RNs and physicians act as an integrated team with common training, where one professional learns from the other and they

work collaboratively. For example, administration of heparin to an ECMO-SP, a procedure that previously required a physician's order, has now become part of the nursing protocol. Registered nurses can now change heparin doses according to a protocol, without a physician's order. The RN is currently required only to inform the physician of any change in the dose. The example of heparin illustrates the concept that protocols can be developed for RNs to titrate a drug on the basis of coagulation test results.

Need for Dedicated ECMO Training

The increase in ECMO use has prompted a need for dedicated training for teams working in the field. The student population in ECMO courses taught in different hospitals might be composed of RNs, perfusionists, and physicians. All the professionals who pass this course will be qualified as ECMO technicians. The course content should be reviewed and endorsed by the ELSO.

Establishment of the Professional Advisory Committee on Nursing Practice in the Care of ECMO-SPs

The focus of the national Professional Advisory Committee was to define evidence-based recommendations for nursing care of ECMO-SPs. The committee was composed of 15 leading senior RNs engaged in management, policy, administration, and education in 11 Israeli intensive care units (ICUs) from 11 medical centers. Of the committee members, 7 were departmental head RNs, 3 were ECMO nursing team leaders, 3 were RNs working in the education field, and 2 were professional guideline administrators. The

committee members met 4 times, with each session lasting approximately 3 hours. During the sessions, the participants analyzed the latest evidence regarding nursing care for ECMO-SPs and shared their professional experiences of providing nursing care for ECMO-SPs. Participants also voiced opinions on the optimal role and scope of practice of RNs in treating ECMO-SPs. The committee reviewed current ECMO-SP treatment in Israel and around the world by appraising the relevant professional literature and the curricula of various educational and training

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programs for RNs. The committee formulated recommendations to establish a hierarchy of professional authorities and identified quality measures and mechanisms for their implementation. Several issues on which the committee reached consensus were prioritized and presented for action and future implementation.

Priority Subjects Identified

The members of the Professional Advisory Committee provided recommendations concerning several issues related to the treatment of ECMO-SPs. In their opinion, the following issues were the most urgent:

- 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 (eg, generalist RNs and advanced practice RNs)
- Providing appropriate content for the various training programs available, such as generic, above-basic, and clinical specialization programs
- Defining quality measures/indexes for treating ECMO-SPs
- Implementing professional guidelines

Determining Boundaries of RNs' Professional Authority and Responsibility

Extracorporeal membrane oxygenation is usually carried out by a multidisciplinary team consisting of physicians, RNs, and perfusionists.⁸ Responsibilities may vary depending on how many people are involved in the task, and there is currently no global agreement as to the optimal ratio of RNs

to ECMO-SPs.

According to the ELSO guidelines, treatment of ECMO-SPs

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should use a single-caregiver model, with a ratio of 1 RN to 1 patient.¹⁰ In contrast, Priest et al¹¹ and Johnson¹² discussed a 2:1 model, with 1 RN in charge of treating the patient and 1 ECMO technician (nurse or perfusionist) looking after the ECMO machinery and circuit. According to the recommendations of the New Zealand Ministry of Health, caring for each ECMO-SP requires 2 RNs, 1 for the patient and 1 for the ECMO circuit, in the absence of a perfusionist.⁹ Conversely, according to a position paper by the International ECMO Network, the

RN to patient ratio should be between 1:1 and 1:2, with 1 RN assigned to 1 or 2 ECMO-SPs.¹³ In clinical settings where the ECMO-SP is primarily treated by an ICU RN, the ICU RN should be specifically trained to perform both tasks: providing care to the patient and managing the ECMO circuit.¹³

Similarly, there is no agreement regarding the responsibilities of RNs on ECMO teams. According to Priest et al,¹¹ an RN on the ECMO team is primarily responsible for treating the patient and not for managing the ECMO device. However, the responsibilities of the RN may also include blood circulation testing (assessing the circuit tubing for blood clots and air bubbles) and fluid delivery, depending on the patient's hemodynamic state and whether the situation is an emergency. Circumstances might require RNs to undertake operations such as stopping the ECMO device and calling for help in cases of arterial or venous air entry, accidental decannulation, or massive blockage of blood circulation in the ECMO device. The role of the ECMO RN might also include calibrating gas flow and fraction of inspired oxygen or the blood flow device according to the protocol.

According to Mossadegh,¹⁴ an RN in charge of a patient supported by ECMO must perform a head-to-toe examination of the patient. This examination includes assessment of vital signs; a physical assessment noting signs of hypoperfusion (cold, clammy, and pale skin¹⁵) and diaphoresis; evaluation of neurological status (level of consciousness and bilateral pupillary response); and examination of intravenous catheters, dressings, and ventilation and infusion devices.¹⁴ In addition to these tests, the RN monitors the ECMO device and evaluates potential risks associated with the device. Such tests include checks of the circuit (including the device's power supply plug and, on some devices, an additional on/off switch), liquids, air and oxygen, cannulas, tubing, gas mixer activity indicators, alarms, availability and readiness of the unit emergency resuscitation kit, and pressures (venous pressure, arterial pressure, and the pressure difference through the oxygenator).¹⁵ During the regular care of ECMO-SPs, RNs also administer medications, request laboratory tests, and document care.¹⁶

In addition, the treatment of ECMO-SPs includes all usual required nursing care (such as pain management, infection prevention, and skin care) to prevent complications and maintain positive outcomes. Nurses should

Table 1 Committee's main recommendations for extending nurses' responsibilities in treating ECMO-SPs

Stage	Patient treatment	ECMO device
Preparing the patient and the ECMO device	Assessing the patient's clinical condition	Helping prepare the ECMO device
Connecting the patient to the ECMO	Performing cannulation procedure	
Providing continuous treatment and follow-up for ECMO-SP	Monitoring of ECMO-SPs according to body systems using standard assessment tools. Assessing the following: ✓ Neurological status ✓ Respiratory status ✓ Hemodynamic status ✓ Fluids and electrolyte balance ✓ Kidney function ✓ Nutritional status ✓ Infectious status ✓ Skin integrity, with an emphasis on wound examination and placement of catheters Identifying deterioration in the patient's condition and reporting findings to the attending physician	Monitoring the ECMO device Taking samples from the ECMO device tubing Providing medical treatment through the ECMO device tubes Providing blood and blood products through the ECMO device tubes Providing ongoing operation of the ECMO device Identifying and treating emergency situations
Weaning the patient from the ECMO device according to a prepared protocol	Monitoring the patient Detecting deterioration in the patient's condition	Withdrawing and ending ECMO device support

Abbreviations: ECMO, extracorporeal membrane oxygenation; ECMO-SP, ECMO-supported patient.

prevent complications such as bleeding, clot formation, hemolysis, and decannulation.¹⁴ Dalia et al¹⁷ recommended nursing ECMO-SP care protocols including blood cultures obtained by a nurse ECMO technician, pupil assessment and documentation every 2 hours, daily sedation holidays, and daily sterile dressing changes of the ECMO insertion sites. Emergencies require RNs to notify the physician in cases of bleeding, air in the circuit, accidental decannulation, and lethal arrhythmias or cardiopulmonary resuscitation.¹⁷

One of the committee's main recommendations was to extend RNs' responsibilities in treating ECMO-SPs in a number of areas (Table 1). The Israeli Ministry of Health accepted the committee's recommendations and issued guidelines regulating the role of RNs and the scope of their responsibilities in treating ECMO-SPs. The guidelines are intended for RNs trained in a recognized course in an acute intensive care field, such as an integrated intensive care course, pediatric intensive care course, or neonatal intensive care course. The responsibility for the development and operation of the courses lies with the Nursing Division of the Israeli Ministry of Health. Different intensive care courses make it possible to upgrade the professional work of certified RNs by adding skills, authorities, and areas of responsibility.

Providing Appropriate Content for Training Programs

Extracorporeal membrane oxygenation is a high-risk procedure requiring professional education. The ELSO has published several papers describing ECMO treatment recommendations.¹⁸⁻²⁰ In addition to these ELSO guidelines, certain authors (eg, Van Kiersbilck et al²¹) have recommended areas of knowledge that RNs should study to treat patients effectively and safely. Dalia et al¹⁷ recommended that a qualified RN teach an annual ECMO class for all nursing staff caring for ECMO-SPs. Despite these sporadic recommendations, no standardized educational program for becoming an ECMO RN/specialist has yet been approved by any ministry of health. The committee recommended updating a generic/basic RN training curriculum and made the suggestions described in Table 2.

Treating ECMO-SPs and operating ECMO devices are highly complex and require knowledge, skill, and experience. Generic and above-basic training in ECMO, as recommended by the committee, provides only basic theoretical knowledge, which is insufficient to support skilled and independent treatment of ECMO-SPs. For this reason, the committee further recommended the establishment of a dedicated ECMO course that would be recognized by an official authority such as the Israeli Ministry of

Table 2 Committee recommendations for updating generic/basic and above-basic nurse training curricula

Educational program	Main subjects	Hours
Generic/basic training	Introduction to ECMO treatment Indications and contraindications Introduction to different types of ECMOs	2 Academic hours
Above-basic training Integrated intensive care course Pediatric intensive care course Neonatal care intensive care course Emergency medicine course	Management of ECMO device Multidisciplinary teams in ECMO-SP treatment Nurses' role in the care of ECMO-SPs	2 Academic hours

Abbreviations: ECMO, extracorporeal membrane oxygenation; ECMO-SP, ECMO-supported patient.

Health to authorize RNs to treat ECMO-SPs. The recommendation included course content, hours of study, required practical experience, methods of examining the students, and method of issuing an ECMO license. The committee recommended periodic training renewal, including ECMO license renewal, similar to training for treatment of acute conditions (eg, ICU courses). The committee also recommended that the course content match the professional standards for ICU training laid out by the ELSO and that the course be recognized by the ELSO to ensure updates to current professional knowledge and compliance with international standards.

The COVID-19 pandemic has created a huge need to train large numbers of additional ECMO technicians in various professions, such as nurses, perfusionists, and physicians. However, opening an ELSO-endorsed course is currently impossible because during the pandemic,

an ELSO representative cannot be present to endorse the course.

Introducing international standards would ensure the safety and effectiveness of ECMO-SP nursing care through quality and risk management.

Therefore, to train new ECMO technicians, the Israel ECMO Society has implemented the ELSO requirements, aiming to obtain future ELSO endorsement of the course. The ECMO course is urgent because ECMO technicians must be trained to provide care to ECMO-SPs with COVID-19. In addition to the designated course, the committee recommended establishing an internal training program in every ICU that provides ECMO treatment.

Globally, nurses and midwives account for approximately 50% of health care professionals.²² Nurses function

as leaders in areas such as practice, education, and research. Defining nurses' authority and responsibilities in the treatment of ECMO-SPs might give nurses an opportunity to take action, to invest their training and experience, and to strengthen nursing leadership, ensuring their role in the development of policy and the treatment of ECMO-SPs.

The definitions proposed by the committee for the scope of practice, responsibilities, and training of nurses may have implications for a variety of areas. However, hospitals with a low frequency of ECMO-SP treatments may have limited ability to accept the proposed changes in nurses' scope of practice, responsibilities, and training. Management teams in centers with a low frequency of ECMO treatment will need to make decisions according to their centers' specific needs.

Defining Relevant Quality Measures

Quality measures are defined as "tools that help us measure or quantify healthcare processes, outcomes, patient perceptions, and organizational structure and/or systems."²³ Because no detailed quality measures for ECMO treatment appeared in the literature, the committee recommended creating detailed quality measures corresponding to nursing practice (Table 3).

Implementing Guidelines

The committee recommended implementing ongoing controls in the following areas:

- Use of RNs' professional potential in the field of acute care and in exceptional activities, subject to approval by authorities such as the Israeli Ministry of Health
- Development of quality controls to be adopted by the Ministry of Health

Table 3 Committee recommendations for defining relevant quality measures

Measure	Characteristics	Explanation and measurement method
Skin integrity	Assess and manage pressure ulcers.	ECMO-SPs experience low tissue perfusion and have a high risk for developing pressure ulcers. Monitoring skin integrity regularly (once every 8 hours) is necessary.
Pain assessment according to the CPOT	Use the CPOT to estimate pain in patients receiving or not receiving mechanical ventilation who are unable to report pain intensity. This scale is intended for use in the ICU.	ECMO is an invasive treatment. Periodic pain assessment is required and should be done according to this tool, which measures pain level on a scale of 0 to 8.
RASS, followed by the CAM-ICU	Use the RASS score to assess sedation depth and the CAM-ICU to determine the presence of delirium.	Treatment with ECMO requires continuous sedation; scales are required to assess sedation depth and delirium.
Bowel movements	Assess the presence of bowel movements. Record the number of defecations per day.	Treatment with ECMO requires administration of drugs with adverse effects, including slower bowel activity and constipation. Follow-up and intervention in this area are required.
Body heat regulation	Obtain body temperature measurements to maintain temperature within the normal range.	ECMO-SPs are affected by the temperature of the blood circulating in the outer circulation path. The ECMO device is equipped with heat-regulation devices that are subject to operation and control.

Abbreviations: CAM-ICU, Confusion Assessment Method for the ICU; CPOT, Critical-Care Pain Observation Tool; ECMO, extracorporeal membrane oxygenation; ECMO-SP, ECMO-supported patient; ICU, intensive care unit; RASS, Richmond Agitation-Sedation Scale.

Recommendations for International Standards for RNs Treating ECMO-SPs and Using ECMO Devices

No international standards for nursing care of ECMO-SPs currently exist. Introducing international standards would ensure the safety and effectiveness of ECMO-SP nursing care through quality and risk management. International standards would also help establish new evidence-based nursing practices.

Formulation of Israeli Ministry of Health Guidelines for Professions Involved in ECMO

The committee's recommendations regarding the enhanced role of nurses in ECMO-SP treatment were submitted for examination by the Israeli Ministry of Health because of the need for interprofessional collaboration of all sectors concerned, including RNs, perfusionists, and physicians. The Israeli Ministry of Health committee has been divided into a number of subcommittees that will examine the scope of responsibilities of each of the professions involved, with an emphasis on RNs and perfusionists. Topics to be considered include professional training for RNs and perfusionists, their competencies and responsibilities, and the creation of standards and regulatory procedures with reference to

the rates of RNs and perfusionists according to the number of ECMO devices and ECMO treatments in a particular medical center. The Professional Advisory Committee is aware that the work should be carried out in full cooperation with other medical professionals (such as perfusionists and physicians) involved in ECMO-SP treatment. Following submission of the draft recommendation to the Israeli Ministry of Health, a circular with guidelines for all professions involved in ECMO treatment will be issued.

Need for Evidence-Based Outcomes

The recommendations of the committee regarding the scope of practice, educational programs, and introduction of quality measures in the treatment of ECMO-SPs are based on the clinical experience and knowledge of the committee members but are not evidence based. Future studies providing evidence-based outcomes from other countries following the committee's suggestions are recommended.

Conclusions

Qualified and safe nursing care for ECMO-SPs can only be provided when RNs are aware of the boundaries of their professional authority and the scope of their practice and responsibilities within the interdisciplinary

ECMO team. Moreover, RNs around the world require adequate preparation and evidence-based quality measures to be able to care for ECMO-SPs. [CCN](#)

Financial Disclosures
None reported.

See also

To learn more about extracorporeal membrane oxygenation, read “Curriculum to Introduce Critical Care Nurses to Extracorporeal Membrane Oxygenation” by Gannon et al in the *American Journal of Critical Care*, 2020;29(4):262-269. Available at www.ajconline.org.

References

1. Squiers JJ, Lima B, DiMaio JM. Contemporary extracorporeal membrane oxygenation therapy in adults: fundamental principles and systematic review of the evidence. *J Thorac Cardiovasc Surg*. 2016;152(1):20-32. doi:10.1016/j.jtcvs.2016.02.067
2. Extracorporeal Life Support Organization. ECLS registry report. July 2020. Accessed January 25, 2021. <https://www.else.org/Registry/Statistics/InternationalSummary.aspx>
3. Sauer CM, Yuh DD, Bonde P. Extracorporeal membrane oxygenation use has increased by 433% in adults in the United States from 2006 to 2011. *ASAIO J*. 2015;61(1):31-36. doi:10.1097/MAT.0000000000000160
4. Maxwell BG, Powers AJ, Sheikh AY, Lee PH, Lobato RL, Wong JK. Resource use trends in extracorporeal membrane oxygenation in adults: an analysis of the Nationwide Inpatient Sample 1998-2009. *J Thorac Cardiovasc Surg*. 2014;148(2):416-21.e1. doi:10.1016/j.jtcvs.2013.09.033
5. Global map. Johns Hopkins University & Medicine Coronavirus Resource Center. Accessed January 23, 2021. <https://coronavirus.jhu.edu/map.html>
6. MacLaren G, Fisher D, Brodie D. Preparing for the most critically ill patients with COVID-19: the potential role of extracorporeal membrane oxygenation. *JAMA*. 2020;323(13):1245-1246. doi:10.1001/jama.2020.2342
7. Ramanathan K, Antognini D, Combes A, et al. Planning and provision of ECMO services for severe ARDS during the COVID-19 pandemic and other outbreaks of emerging infectious diseases. *Lancet Respir Med*. 2020; 8(5):518-526. doi:10.1016/S2213-2600(20)30121-1
8. Abrams D, Garan AR, Abdelbary A, et al; International ECMO Network (ECMONet) and The Extracorporeal Life Support Organization (ELSO). Position paper for the organization of ECMO programs for cardiac failure in adults. *Intensive Care Med*. 2018;44(6):717-729. doi:10.1007/s00134-018-5064-5
9. New Zealand Ministry of Health. Service model: extra corporeal membrane oxygenation (ECMO). May 2017. Accessed January 4, 2021. https://nsfl.health.govt.nz/system/files/documents/pages/service_model_-_ecmo_consultation_version_0.pdf
10. Extracorporeal Life Support Organization. ELSO guidelines for ECMO centers. Version 1.8. March 2014. Accessed January 4, 2021. <https://www.else.org/Portals/0/IGD/Archive/FileManager/faf3f6a3c7cusersshydocumentselsoguidelinesecmocentersv1.8.pdf>
11. Priest MA, Beaty C, Ogino M. Training of nurses and continuing education in ECMO. In: Mossadegh C, Combes A, eds. *Nursing Care and ECMO*. Springer International Publishing; 2017:109-125. doi:10.1007/978-3-319-20101-6_12
12. Johnson C. Design, organization and staffing of the intensive care unit. *Surgery (Oxford)*. 2018;36(4):159-165. doi:10.1016/j.mpsur.2018.01.007
13. Combes A, Brodie D, Bartlett R, et al; International ECMO Network (ECMONet). Position paper for the organization of extracorporeal membrane oxygenation programs for acute respiratory failure in adult patients. *Am J Respir Crit Care Med*. 2014;190(5):488-496. doi:10.1164/rccm.201404-0630CP
14. Mossadegh C. Monitoring the ECMO. In: Mossadegh C, Combes A, eds. *Nursing Care and ECMO*. Springer International Publishing; 2017:45-70. doi:10.1007/978-3-319-20101-6_5
15. Bonanno FG. Clinical pathology of the shock syndromes. *J Emerg Trauma Shock*. 2011;4(2):233-243. doi:10.4103/0974-2700.82211
16. Guglin M, Zucker MJ, Bazan VM, et al. Venoarterial ECMO for adults: JACC scientific expert panel. *J Am Coll Cardiol*. 2019;73(6):698-716. doi:10.1016/j.jacc.2018.11.038
17. Dalia AA, Ortoleva J, Fiedler A, Villavicencio M, Shelton K, Cudemus GD. Extracorporeal membrane oxygenation is a team sport: institutional survival benefits of a formalized ECMO team. *J Cardiothorac Vasc Anesth*. 2019;33(4):902-907. doi:10.1053/j.jvca.2018.06.003
18. Extracorporeal Life Support Organization. ELSO guidelines for training and continuing education of ECMO specialists. Version 1.5. February 2010. Accessed January 4, 2021. <http://www.else.org/portals/0/igd/archive/filemanager/97000963d6cusersshydocumentselsoguidelinesfortrainingandcontinuingeducationofecmospecialists.pdf>
19. Ogino MT, Chuo J, Short BL. ECMO administrative and training issues, and sustaining quality. In: Annich GM, Lynch WR, MacLaren G, Wilson JM, Bartlett RH, eds. *ECMO: Extracorporeal Cardiopulmonary Support in Critical Care*. 4th ed. Extracorporeal Life Support Organization; 2012: 479-495.
20. Brogan TV, Annich G, Ellis WC, Haney B, Heard ML, Lorusso R, eds. *ECMO Specialist Training Manual*. 4th ed. Extracorporeal Life Support Organization; 2018.
21. Van Kiersbilck C, Gordon E, Morris D. Ten things that RNs should know about ECMO. *Intensive Care Med*. 2016;42(5):753-755. doi:10.1007/s00134-016-4293-8
22. World Health Organization. 2020. Accessed at January 26, 2021. <https://www.who.int/news-room/fact-sheets/detail/nursing-and-midwifery>
23. Quality measures. Centers for Medicare & Medicaid Services. Accessed January 27, 2021. <https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/QualityMeasures>