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Position paper on global ECMO education and educational agenda for the future: a statement from the extracorporeal life support organization ECMOed taskforce

Zakhary, B.; Shekar, K.; Diaz, R.; Badulak, J.; Johnston, L.; Roeleveld, P.P.; ... ; Extracorporeal Life Support Org EL

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Position Paper on Global Extracorporeal Membrane Oxygenation Education and Educational Agenda for the Future: A Statement From the Extracorporeal Life Support Organization ECMOed Taskforce*

Bishoy Zakhary, MD¹; Kiran Shekar, FCICM, PhD^{2,3,4}; Rodrigo Diaz, MD⁵; Jenelle Badulak, MD⁶; Lindsay Johnston, MD, MEd⁷; Peter Paul Roeleveld, MD⁸; Guillaume Alinier, PhD, MPhys, PGCert^{9,10,11,12}; Peter Chi Keung Lai, MN, PGDip (ICN), RN, FHKAN (Critical Care)¹³; Kollengode Ramanathan, MD¹⁴; Elizabeth Moore, BSN, RN, MBA¹⁵; Ibrahim Hassan, MD^{16,17}; Cara Agerstrand, MD¹⁸; Wallace Chun-wai Ngai, MBChB¹⁹; Leonardo Salazar, MD²⁰; Lakshmi Raman, MD²¹; Melania M. Bembea, MD, MPH, PhD²²; Mark Davidson, MD²³; Rene D. Gomez-Gutierrez, MD²⁴; Jose Alfonso Rubio Mateo-Sidrón, MD²⁵; Jeannie Kukutschka, MD²⁶; Marta V. Antonini, CCN, CCP, MS²⁷; Marc L. Dickstein, MD²⁸; Matthieu Schmidt, MD, PhD²⁹; Darryl Abrams, MD¹⁸; Mark T. Ogino, MD^{30,31}; on behalf of the Extracorporeal Life Support Organization (ELSO) ECMOed Taskforce

*See also p. 435.

¹Division of Pulmonary and Critical Care, Oregon Health and Science University, Portland, OR.

²Adult Intensive Care Services and Critical Care Research Group, The Prince Charles Hospital, Brisbane, QLD, Australia.

³University of Queensland, Brisbane, QLD, Australia.

⁴Bond University, Gold Coast, QLD, Australia.

⁵Clinica Las Condes, Santiago, Chile.

⁶University of Washington, Seattle, WA.

⁷Yale School of Medicine, New Haven, CT.

⁸Department of Pediatric Intensive Care, Leiden University Medical Center, Leiden, The Netherlands.

⁹Research Department, Hamad Medical Corporation Ambulance Service, Doha, Qatar.

¹⁰School of Health and Social Work, University of Hertfordshire, Hatfield, United Kingdom.

¹¹Weill Cornell Medicine – Qatar, Doha, Qatar.

¹²Faculty of Health and Life Sciences, Northumbria University, Newcastle Upon Tyne, United Kingdom.

¹³Adult Intensive Care Unit, Queen Mary Hospital, Hong Kong.

¹⁴Cardiothoracic Intensive Care Unit, National University Heart Centre, Singapore.

¹⁵Heart and Vascular Center, University of Iowa Hospitals and Clinics, Iowa City, IA.

¹⁶Hamad Medical Corporation, Doha, Qatar.

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¹⁷Weill Cornell Medical College, New York, NY.

¹⁸Division of Pulmonary, Allergy, and Critical Care, Columbia University College of Physicians and Surgeons/NewYork-Presbyterian Hospital, New York, NY.

¹⁹Adult Intensive Care Unit, Queen Mary Hospital, Hong Kong.

²⁰Department of ECMO and VAD, Fundación Cardiovascular de Colombia, Bucaramanga, Colombia.

²¹University of Texas Southwestern Medical Center, Dallas, TX.

²²Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD.

²³Department of Paediatric Intensive Care, Royal Hospital for Children, Glasgow, United Kingdom.

²⁴Christus Muguerza Hospital Alta Especialidad, Universidad de Monterrey, San Pedro Garza García, Mexico.

²⁵University Hospital Foundation Jiménez Díaz, Madrid, Spain.

²⁶ECMO Center, Christus Muguerza Hospital Alta Especialidad, Universidad de Monterrey, San Pedro Garza García, Mexico.

²⁷ICU I° Department of Anesthesia and Intensive Care, University Hospital of Parma, Parma, Italy.

²⁸Department of Anesthesiology, College of Physicians and Surgeons, Columbia University, New York, NY.

²⁹Sorbonne Université, INSERM UMRS_1166 - iCAN, Institute of Cardiometa-bolism and Nutrition, Assistance Publique - Hôpitaux de Paris, Pitié - Salpêtrière Hospital, Medical Intensive Care Unit, 75651 Paris Cedex 13, France.

³⁰Department of Pediatrics, Division of Neonatology, Nemours Alfred I duPont Hospital for Children, Wilmington, DE

³¹Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA.

All members of the Extracorporeal Life Support Organization (ELSO) ECMOed Taskforce can be viewed in **Appendix 1** (Supplemental Digital Content 1,).

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (<http://journals.lww.com/ccmjournal><http://links.lww.com/CCM/F213>).

All members of ECMOed disclosed that the Unidad Extracorporeal Membrane Oxygenation (ECMO) Clinica Las Condes (Santiago, Chile) provided travel and accommodation funding for the first ECMOed Taskforce meeting in Santiago, Chile, and the Hamad Medical Corporation (HMC, Doha, Qatar), the HMC Hamad International Training Center, and the HMC Medical Education Department (Doha, Qatar) provided travel and accommodation funding for the second ECMOed Taskforce meeting in Doha, Qatar. Dr. Shekar received grant funding from National Health and Medical Research Council, The Prince Charles Hospital Foundation, Intensive Care Foundation, Australia and New Zealand College of Anaesthetists, Queensland Emergency Medicine Research Foundation, and Defense Health Foundation and the Extracorporeal Life Support Organization (ELSO). Dr. Diaz disclosed off-label product use of ECMO. Dr. Johnston is an investigator on the following grants: National Institutes of Health (NIH) 1R21HD089151-01A1: Improving safety and quality of tracheal intubations in neonatal ICUs; University of Pennsylvania Support for Projects Advancing Research and Knowledge in Education (SPARK-Ed) Medical Education Research & Innovation: The ONTPD National Neonatology Flipped Classroom Curriculum and the Development of Best Practices for Flipped Classroom Facilitation; American Academy of Pediatrics Section on Neonatal-Perinatal Medicine: The (Organization of Neonatal-Perinatal Training Program Directors (ONTPD) National Neonatology Curriculum Project. Dr. Alinier has the following grants from the Qatar National Research Fund and Qatar University: UREP22-003-2-001: Human Circulatory System Simulation for ECMO Therapy; UREP19-062-2-026 and QUST-CENG-SPR-15/16-8: ECMO Simulator for Patient Management Training at HMC; QUST-CENG-2018-1: Revolutionizing ECMO Simulation with Affordable yet High-Fidelity Technology. U.S. Patent App. 16/271,651, 2019: Using thermochromic ink for blood simulation in medical training. Dr. Ramanathan received travel grants from Medtronic. He is the lead site investigator for the following funded trials: Preventing Systemic Inflammation After Cardiac Surgery With Alkaline Phosphatase (APPIRED-III), APTREAT trials; and a co-investigator of the following funded trial: EPIC trial. Dr. Moore received funding from Zoll. Dr. Salazar received educational fees from Abbott. Dr. Bembea's institution received funding from the NIH/National Institute of Neurological Disorders and Stroke and the Eunice Kennedy Shriver National Institute of Child Health and Human Development. Dr. Dickstein has received lecture fees from Abiomed, Zoll, and LivaNova. He also has equity interest in PVLoops. Dr. Schmidt is the lead investigator of the following funded trials: PRONECMO, DRESSING-ECMO. He has received lecture fees from Getinge, Dräger, and Xenios. Dr. Ogino's institution received travel support funding from ELSO, Euro-ELSO, LA ELSO, SWAAC ELSO, University of Texas Southwestern, Fundacion Cardiovascular de Colombia Bucaramanga, Clinica las Condes, IRCAD (Institut de Recherche contre les Cancers de l'Appareil Digestif) Brazil, Chinese Society Extracorporeal Life Support, Great Wall Congress, General Hospital of Peoples Liberation Army, Japan Society of Clinical Anesthesia, Temporary Circulatory Support ECMO Congress, Turkish Critical Care Medicine Society, Hamad Medical Corporation, Sidra Medical Center, and ECMO Society of India. The remaining authors have disclosed that they do not have any potential conflicts of interest.

For information regarding this article, E-mail: bzakhary@gmail.com

Objectives: The purpose of this position paper is two-fold: first, to describe the state of extracorporeal membrane oxygenation education worldwide, noting current limitations and challenges; and second, to put forth an educational agenda regarding opportunities for an international collaborative approach toward standardization.

Design: Relevant medical literature was reviewed through literature search, and materials from national organizations were accessed through the Internet. Taskforce members generated a consensus

statement using an iterative consensus process through teleconferences and electronic communication.

Setting: In 2018, the Extracorporeal Life Support Organization convened the ECMOed Taskforce at two structured, face-to-face meetings of 40 healthcare practitioners and educators with expertise in caring for the extracorporeal membrane oxygenation patient and in extracorporeal membrane oxygenation education.

Patients: None.

Interventions: None.

Measurements and Main Results: The ECMOed Taskforce identified seven educational domains that would benefit from international collaborative efforts. Of primary importance, the Taskforce outlined actionable items regarding 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; and 5) promoting high-quality educational research to guide ongoing educational and competency assessment development.

Conclusions: Significant variability and limitations in global extracorporeal membrane oxygenation education exist. In this position paper, we outline a road map for standardizing international extracorporeal membrane oxygenation education and practitioner certification. Ongoing high-quality educational research is needed to evaluate the impact of these initiatives. (*Crit Care Med* 2020; 48:406–414)

Key Words: certification; education; Extracorporeal Life Support Organization; extracorporeal membrane oxygenation

Use of extracorporeal membrane oxygenation (ECMO) has grown dramatically over the past 15 years with 10- and four-fold increases in adult and pediatric ECMO cases, respectively (1, 2). Although the number of global ECMO centers is unknown, the number of hospitals reporting data to the Extracorporeal Life Support Organization (ELSO) registry has increased from 83 in 1990 to 375 in 2018 (3). Although advancements in circuit technology (4, 5), experience during the 2009 H1N1 pandemic (6, 7), and encouraging results from two modern trials (8, 9) and a post hoc Bayesian analysis (10) have helped fuel this increased uptake, the management of patients requiring ECMO support remains technically challenging (11, 12) with variability in global complications and outcomes (13). Such variability likely reflects differences in patient selection, ECMO application, and patient management, factors well suited to standardization through education.

In an effort to improve clinical outcomes, ELSO has promoted specialized education for ECMO practitioners by putting forth training guidelines for ECMO centers (13) and suggesting certification standards for ECMO practitioners (14). Despite these recommendations, ECMO education and certification remain limited and variable (15). In particular,

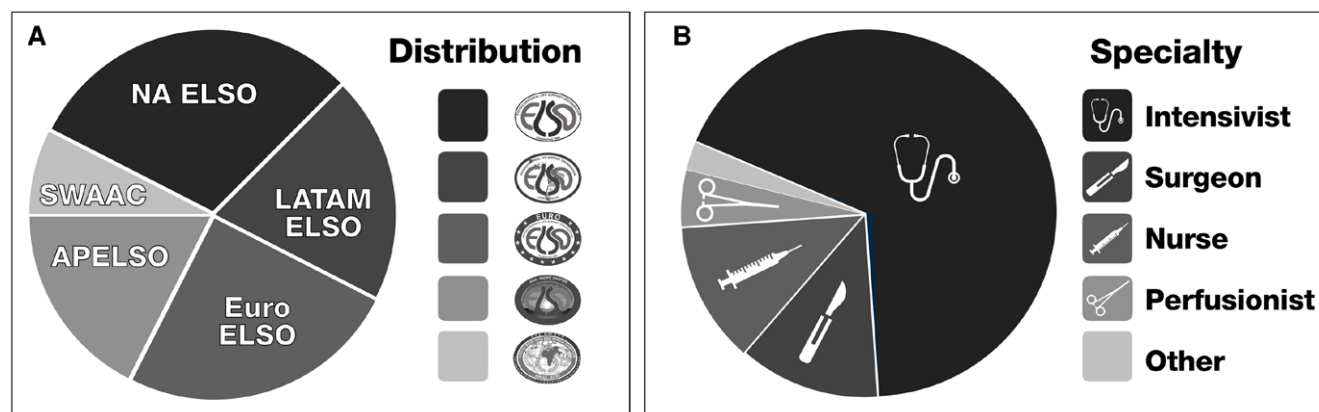


Figure 1. ECMOed membership. The ECMOed Taskforce is composed of an international group of 40 healthcare practitioners and educators with expertise in caring for the extracorporeal membrane oxygenation (ECMO) patient and in ECMO education. Membership is broadly international, representing all five international Extracorporeal Life Support Organization (ELSO) chapters, and broadly multidisciplinary, representing the different specialties and disciplines involved in ECMO care. AP = Asian-Pacific, Euro = European, LATAM = Latin American, NA = North American, SWAC = South and West Asian and African.

lack of a standardized ECMO curriculum, course structure, and certification criteria have hindered a systematic implementation by ECMO centers. To address these concerns, the ELSO ECMOed Taskforce was created and charged with identifying global ECMO educational needs and outlining mechanisms for international collaboration and standardization.

ECMOED TASKFORCE

The ECMOed Taskforce is composed of a nominated group of 40 healthcare practitioners and educators from 19 countries with expertise in caring for the ECMO patient and in ECMO education (Fig. 1). All five international ELSO chapters are represented, including the North American, Latin American, European, South and West Asian and African, and Asian-Pacific chapters, imparting a global perspective on ECMO practice. Membership is broadly multidisciplinary representing the different specialties and disciplines involved in ECMO care. Among the adult, pediatric, and neonatal practitioners are intensivists, surgeons, anesthesiologists, pulmonologists, cardiologists, emergency physicians, ECMO specialists, nurses, perfusionists, and simulation experts.

This consensus statement is the result of two face-to-face meetings, teleconferences, and electronic communication among the ECMOed Taskforce members. Based on a review of published literature, the current state of ECMO education was assessed and described, key educational domains were identified, and preliminary recommendations were made. Workgroups were constituted to evaluate each of these domains, and consensus was arrived at using the nominal group technique (16). Proceedings with the Taskforce's recommendations and rationales are presented in this article.

The purpose of this position paper is two-fold: first, to describe the state of ECMO education worldwide as it pertains to each workgroup domain noting current limitations and challenges; and second, to put forth an educational agenda regarding opportunities for an international collaborative approach toward standardization within each domain. The article is aimed toward ECMO practitioners, healthcare professionals (e.g., physicians, nurses, respiratory therapists, perfusionists) involved in the bedside care of the ECMO circuit and

patient, ECMO program directors and coordinators, hospital directors, and regional healthcare organizers with the goal of ensuring that ECMO care is delivered safely and proficiently in a manner that is consistent and of high quality across the globe.

KEY DOMAINS OF ECMO EDUCATION

The ECMOed Taskforce identified educational domains that would benefit from international collaborative efforts. Domains were chosen to be sufficiently comprehensive to capture important elements of ECMO education while minimizing overlap. The Taskforce prioritized 1) creating a standardized ECMO curriculum; 2) defining criteria for an ECMO course as a vehicle for delivering the curriculum; 3) outlining a mechanism for evaluating the quality of educational offerings; 4) utilizing these tools in the development of ECMO practitioner assessment and certification; and 5) promoting high-quality educational research to guide ongoing educational and competency assessment development.

Based on these priorities, the Taskforce listed the following four categories encompassing seven educational workgroups: Generating Content containing the ECMO Curriculum workgroup; Delivering Content encompassing the ECMO Courses, ECMO Workshops, and Online ECMO Education workgroups; Governance containing the ECMO Course and Workshop Endorsement and the ECMO Certification workgroups; and Quality Assurance containing the ECMO Educational Research workgroup. ECMOed members were divided into seven workgroups, based on experience and expertise, to assess and make recommendations within each domain. Workgroup summaries with recommendations and associated rationales are presented below and summarized in Table 1.

ECMOED WORKGROUP SUMMARIES

Generating Content

ECMO Curriculum

Recommendations

1. Organize an international and multidisciplinary expert group to develop a standardized ECMO curriculum

incorporating both knowledge and psychomotor skill learning objectives defining minimal competency of the ECMO practitioner.

Rationale. The foundational elements of ECMO education are dependent on the development of a rigorous and standardized curriculum. Standardization of curricula is widely accepted and employed by governing medical education organizations including the American College of Graduate Medical Education (17) and the Liaison Committee on Medical Education (18). As ECMO use grows and clinical practice guidelines are outlined, a standardized curriculum can help ensure best practices are met.

Since their publication, the ELSO Red Book (19) and the ELSO Specialist Manual (20), as well as the ELSO Guidelines for Training and Continuing Education of ECMO Specialists (13), have been adapted by ECMO centers to compose ECMO curricula for local education. More recently, several institutions have published their experiences with ECMO curriculum development and assessment (21–26), whereas others have advertised ECMO courses and curricula online (27–34). Limitations of current curricula include the inherent lack of generalizability, being subject to regional variations in practice and lacking international input. Furthermore, published works have not used the rigorous methodology necessary for curriculum development and application (35, 36).

To meet the goal of a rigorously developed and widely generalizable ECMO curriculum, the ECMOed Curriculum Workgroup has put forth a proposal based on Kern's methodology (37) for an expert panel consensus curriculum with validity and reliability testing (Fig. 2) covering the appropriate levels of Bloom's taxonomy (38). A thoughtfully developed curriculum is the ideal vehicle to deliver excellence in ECMO education and practitioner training. In particular, the curriculum will form the foundation for ECMO courses, facilitate the development of online ECMO content, allow for endorsement criteria of ECMO educational offerings, and set the structural framework for an ECMO practitioner certification process.

Delivering Content

ECMO Courses

Recommendations

2. Define Comprehensive ECMO Courses to 1) meet all ECMO curricular knowledge and psychomotor skill learning objectives and 2) achieve a minimal educational quality level.

Rationale. The growth in the number of ECMO centers has mandated the need to train large number of ECMO practitioners and has been associated with numerous ECMO educational offerings. ECMO courses are currently being organized throughout the world and are offered by ELSO (27), by academic institutions (28, 29, 34, 39–41), by industry (42, 43), and in concert with societal meetings (44–47). Target learner groups are variable and include nurses (24), residents and fellows (22, 25, 26), and interprofessional groups (21, 23).

Although each educational offering aims to provide an overview of ECMO support, there is variability in training methods, curricular coverage, training duration, instructor qualifications,

TABLE 1. Summary of ECMOed Taskforce Recommendations

| |
|--|
| Generating Content |
| ECMO Curriculum |
| 1. Organize an international and multidisciplinary expert group to develop a standardized ECMO curriculum incorporating both knowledge and psychomotor skill learning objectives defining minimal competency of the ECMO practitioner. |
| Delivering Content |
| ECMO Courses |
| 2. Define Comprehensive ECMO Courses to 1) meet all ECMO curricular knowledge and psychomotor skill learning objectives and 2) achieve a minimal educational quality level. |
| ECMO Workshops |
| 3. Supplement Comprehensive ECMO Courses with workshops that enrich and expand on the curriculum. |
| Online ECMO Education |
| 4. Create an online ECMO course targeting ECMO practitioners and meeting all ECMO curricular knowledge learning objectives. |
| Governance |
| ECMO Course and Workshop Endorsement |
| 5. Outline a procedure for evaluating and endorsing ECMO courses and workshops. |
| ECMO Certification |
| 6. Outline an ECMO certification process incorporating validated assessment tools mapped to the curricular knowledge and psychomotor skill learning objectives of the ECMO curriculum. |
| Quality Assurance |
| ECMO Educational Research |
| 7. Perform systematic research incorporating both qualitative and quantitative methods to delineate effective teaching methods and tools, reliable outcome measures, and successful educational programs. |

ECMO = extracorporeal membrane oxygenation.

target learners and participants, and course assessment. Although the need to define an ECMO curriculum is of paramount importance, the method by which the curriculum is subsequently delivered must also be delineated. This is particularly important given local credentialing requirements typically incorporate a form of initial and ongoing ECMO education (15) such that ECMO courses have an inherent high-stakes value attached.

Defining a Comprehensive ECMO Course, therefore, is needed both to ensure that curricular requirements are met and appropriate educational quality is achieved. To this end, ECMO courses should meet all ECMO curricular knowledge and psychomotor skill learning objectives, should target all healthcare professionals involved in providing direct bedside ECMO care, and incorporate a rigorously developed learner assessment and course evaluation. Other elements that make up course structure,

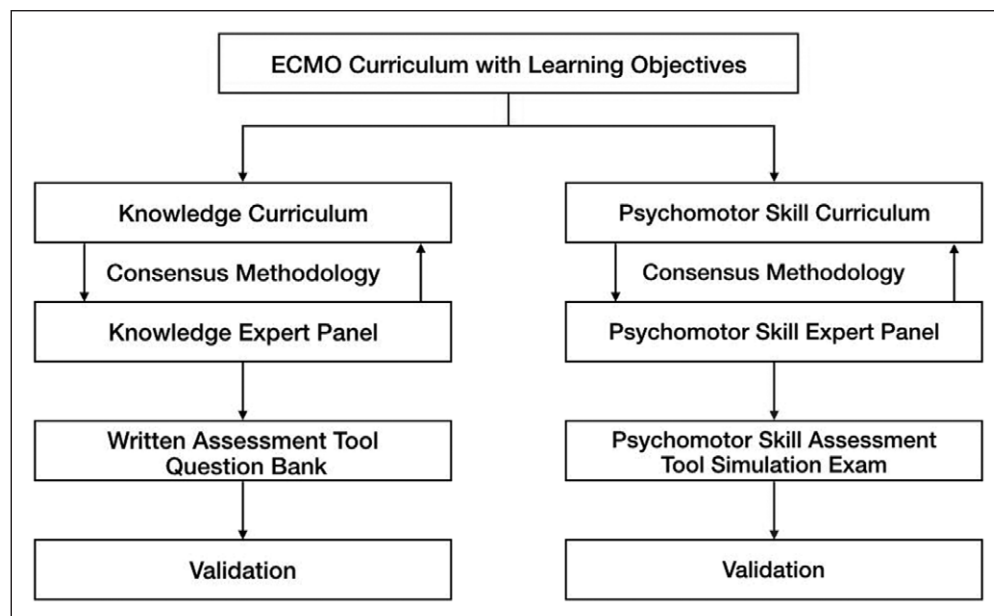


Figure 2. ECMOed Curriculum Workgroup proposal for the development of a rigorously developed and widely generalizable and standardized extracorporeal membrane oxygenation (ECMO) curriculum. The proposal is based on Kern's methodology for an expert panel consensus curriculum with validity and reliability testing. After compiling knowledge and psychomotor skill learning objectives, an external international and multidisciplinary expert panel will use iterative consensus methodology to define the curricula. Development of knowledge and psychomotor skill assessment tools mapped to their respective learning objectives will subsequently be subject to validity and reliability testing to ensure they achieve their task of differentiating ECMO competency level.

including center and course director experience, training methods, role and fidelity of simulation, course duration, instructor qualifications, learner-to-instructor ratio, commercial relationships, and advertising regulations also require delineation.

ECMO Workshops

Recommendations

3. Supplement Comprehensive ECMO Courses with workshops that enrich and expand on the curriculum.

Rationale. Workshops are focused educational offerings outside the curricular criteria of a Comprehensive ECMO Course. Since the ECMO curriculum aims to define learning objectives applicable to all ECMO practitioners, advanced topics and discipline-specific topics may not be fully addressed in the courses. ECMO workshops can be tailored to the needs of specific learners to enrich the ECMO curriculum by offering focused didactic and simulation training.

Workshops are typically limited in scope and duration and can be offered in collaboration with other societies at national or international meetings. Examples include the ECMO Overview (33, 48) and Advanced Venous-ECMO (46, 49) workshops. Alternatively, workshops can be offered as stand-alone events addressing advanced and focused principles of ECMO management such as the ECMO Cannulation (30, 31) and Extracorporeal Cardiopulmonary Resuscitation (50, 51) workshops. Workshops can also be developed within the context of a broader physiologic topic. A mechanical circulatory support workshop utilizing advanced hemodynamic physiology simulation software presents the role of

venoarterial ECMO among other mechanical devices in supporting cardiogenic shock (32). Workshops integrating ECMO within a broader management paradigm are likely to become more common as ECMO indications expand.

Online ECMO Education Recommendations

4. Create an online ECMO course targeting ECMO practitioners and meeting all ECMO curricular knowledge learning objectives.

Rationale. Online learning has become an integral component of medical education with web-based journals, webinars, blogs, and social media increasingly adopted to supplement or replace traditional learning methods (52, 53). Online education allows for greater reach and dispersion of standardized content,

promotes self-directed and asynchronous learning, and offers interactive and real-time feedback (54, 55). Current online ECMO educational offerings include video voiceover lectures (56, 57), case-based modules (58, 59), webinars (60), and blog articles and editorials (50, 59). Although innovative, they are limited in scope, covering select portions of an ECMO curriculum, and not always subject to peer review. Authors are typically from a single institution, restricting applicability as an international resource, and content is primarily designed for physician learners, with limited material available for other ECMO practitioners.

The benefits of a comprehensive high-quality online ECMO course are evident. First, a web-based educational program can expand global reach while promoting widespread implementation of a standard ECMO curriculum. Second, an online course meeting all curricular knowledge learning objectives can prepare learners ahead of in-person ECMO courses. Such a flipped classroom strategy can allow a greater focus on psychomotor skills during courses. Finally, online education can facilitate and expand the deployment of an ECMO practitioner certification program in a manner analogous to the online courses offered for cardiopulmonary resuscitation training as part of the American Heart Association certification (61).

Governance

ECMO Course and Workshop Endorsement

Recommendations

5. Outline a procedure for evaluating and endorsing ECMO courses and workshops.

Rationale. With the increase in ECMO educational offerings, and with the development of a standardized ECMO curriculum and course structure, there will be a need for objective assessment of ECMO courses. An endorsement process is a means for standardization of educational content while ensuring educational quality. Endorsement of educational activities is well established among societal institutions (62–64) and can be adapted for ECMO use.

There are many potential benefits of endorsement. First, a centralized endorsement process will allow for dissemination of a standardized ECMO curriculum at an international level while ensuring educational standards and quality are met. Second, by ensuring a universal standardized curriculum and minimal educational standards, an endorsement process sets the stage for an ECMO certification program. Modeling the certification process after the American Heart Association for basic life support and advanced cardiac life support courses (61, 65), where training and testing are widely distributed throughout the world, having multiple centers offer a Comprehensive ECMO Course is a necessary framework for a similar program. Finally, an endorsement process offers a direct benefit to course providers by ensuring that the curriculum is complete and that gaps in educational quality are identified.

ECMO Certification

Recommendations

6. Outline an ECMO certification process incorporating validated assessment tools mapped to the curricular knowledge and psychomotor skill learning objectives of the ECMO curriculum.

Rationale. Despite the growth of ECMO course offerings, no professional medical board or society offers ECMO certification. Although ELSO recommends that ECMO centers include staff training with individual certification of practitioners (13), a survey of U.S. ECMO centers determined that, of responding centers, only 57% have institutional ECMO certification programs for ECMO physicians with recertification required at only 16% (15). International practices are largely unknown. Likely contributing to this low level of institutional certification is that available ECMO assessment tools have lacked significant validity evidence (21, 23, 25, 26) and do not reach the high standard of rigor employed in other published medical education assessment tools (66, 67).

There is therefore a need to define and establish a certification process for ECMO practitioners. As described by the Institute for Credentialing Excellence (68), such a process would outline minimal knowledge and skills required to provide ECMO care, allow for standardization of ECMO practice across sites and disciplines, and establish recognition of the unique skill set required for competent ECMO provision.

There are currently no agreed upon criteria for certification of ECMO practitioners. To address this important gap, there is an urgent need to develop and validate assessment tools mapped to the ECMO curriculum (Fig. 2). Further consensus on the role of ECMO courses, online education, instructor and assessor qualifications, and certification infrastructure will also require delineation.

Quality Assurance

ECMO Educational Research

Recommendations

7. Perform systematic research incorporating both qualitative and quantitative methods to delineate effective teaching methods and tools, reliable outcome measures, and successful educational programs.

Rationale. Standardized ECMO education has the potential to positively impact ECMO outcome, and it is on this basis that ELSO promotes specialized training for ECMO practitioners (13). Recommendations, however, are primarily based on expert opinion, and it remains unclear which elements enhance ECMO practice and clinical outcome. Filling this knowledge gap requires a better understanding of current training infrastructures, assessing and validating educational curricula, and calibrating existing training programs to participant needs. Data describing the quality and variability of ECMO education worldwide, however, are lacking, and the effectiveness of different ECMO educational initiatives is unknown.

To this end, international structured surveys and focus group interviews are needed to better define current practices within each of the educational domains. Such data can further inform international educational needs and clarify effective educational systems and teaching methods. To help guide this effort, an open forum facilitating public contributions from and discourse among the diverse group of stakeholders would be of great value. ECMOed will host this forum on social media (<http://bit.ly/ECMOedPP> [Facebook, Menlo Park, CA] and #ECMOedPP [Twitter, San Francisco, CA]) to elicit input in each workgroup domain while also addressing inquiries and comments. Subsequently, as ECMO education undergoes organization and standardization with the recommendations put forth by ECMOed in this document, a responsibility also exists to evaluate the impact of these recommendations and to ensure they achieve their intended goals.

AREAS OF UNCERTAINTY

Several elements of ECMO education remain to be defined and the ECMOed Taskforce has highlighted important opportunities for future research. The recommendations made in this article are primarily based on expert opinion and, despite having representation from all ELSO chapters, may not fully reflect the views of the global ECMO community. Further optimization from external surveys, focus groups interviews, and continued consensus methodology among experts will be beneficial.

It is clear that a more in-depth description of the current state of ECMO education is required. Most data forming the basis of this position paper are derived from published literature from North American and European ECMO programs. Comparatively little is known about educational efforts in South America, Africa, and Asia. Furthermore, ECMO is being delivered in diverse geographic, socioeconomic, linguistic, and cultural settings. Although standardization of global ECMO education is desirable, local adaptations based on needs, resources, and experience will be necessary. Similarly,

in implementing ECMO practitioner certification, centers will have to consider local accreditation processes, governance, legal and quality control mechanisms, and ECMO care delivery models.

It should be noted that this position paper does not address other forms of Extracorporeal Life Support (ECLS) devices. Although there is significant growth in ECLS with promising therapies on the horizon, such as extracorporeal carbon dioxide removal devices, when the Taskforce first met, a decision was made to focus on ECMO as this was the most rapidly growing technology as well as the foundational one for other ECLS devices. Nevertheless, future educational curricula will need to consider the expanding role of such technologies.

Finally, the ultimate goal of the ECMOed Taskforce is to improve the quality of ECMO care and patient outcomes. Establishing a causal relationship between effective ECMO education and ECMO practitioner certification with clinically relevant patient outcome measures is much needed and should be a focus of future research efforts. The goals set forth here are analogous to those of the International ECMO Network, a consortium of ECMO-proficient centers and ECMO experts dedicated to supporting high-quality clinical research (69). ECMOed aims to fill a similar role in promoting best educational practices and setting the framework for ongoing high-quality educational research.

CONCLUSIONS

The ECMOed Taskforce, an international and multidisciplinary group of healthcare practitioners and educators with expertise in ECMO care and education, outlines an educational agenda with recommendations promoting an international collaborative approach toward standardization of ECMO education. Of primary importance is the need for a standardized and rigorously developed ECMO curriculum, defining the structure of a Comprehensive ECMO Course, developing complimentary ECMO workshops, outlining a process for evaluating external ECMO courses, implementing an ECMO practitioner certification process, and developing online ECMO education platforms. High-quality educational research is needed to assess the impact of the recommendations and inform ongoing educational opportunities.

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REFERENCES

- Barbaro RP, Paden ML, Guner YS, et al; ELSO member centers: Pediatric Extracorporeal Life Support Organization registry international report 2016. *ASAIO J* 2017; 63:456–463
- Thiagarajan RR, Barbaro RP, Rycus PT, et al; ELSO member centers: Extracorporeal Life Support Organization registry international report 2016. *ASAIO J* 2017; 63:60–67
- Extracorporeal Life Support Organization: ECLS Registry Report: International Summary. Available at: <https://www.else.org/Registry/Statistics/InternationalSummary.aspx>. Accessed February 22, 2018
- Shekar K, Mullany DV, Thomson B, et al: Extracorporeal life support devices and strategies for management of acute cardiorespiratory failure in adult patients: A comprehensive review. *Crit Care* 2014; 18:219
- Extracorporeal Life Support Organization: General Guidelines for all ECLS Cases. Available at: https://www.else.org/Portals/0/ELSO%20Guidelines%20General%20All%20ECLS%20Version%201_4.pdf. Accessed January 17, 2019
- Davies A, Jones D, Bailey M, et al; Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators: Extracorporeal membrane oxygenation for 2009 Influenza A(H1N1) acute respiratory distress syndrome. *JAMA* 2009; 302:1888–1895
- Pham T, Combes A, Rozé H, et al; REVA Research Network: Extracorporeal membrane oxygenation for pandemic influenza A(H1N1)-induced acute respiratory distress syndrome: a cohort study and propensity-matched analysis. *Am J Respir Crit Care Med* 2013; 187:276–285
- Peek GJ, Mugford M, Tiruvoipati R, et al; CESAR trial collaboration: Efficacy and economic assessment of conventional ventilatory support versus extracorporeal membrane oxygenation for severe adult respiratory failure (CESAR): a multicentre randomised controlled trial. *Lancet* 2009; 374:1351–1363
- Combes A, Hajage D, Capellier G, et al; EOLIA Trial Group, REVA, and ECMONet: Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome. *N Engl J Med* 2018; 378:1965–1975
- Goligher EC, Tomlinson G, Hajage D, et al: Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome and posterior probability of mortality benefit in a post hoc Bayesian analysis of a Randomized Clinical Trial. *JAMA* 2018; 320:2251–2259
- Sidebotham D, McGeorge A, McGuinness S, et al: Extracorporeal membrane oxygenation for treating severe cardiac and respiratory disease in adults: Part 1—overview of extracorporeal membrane oxygenation. *J Cardiothorac Vasc Anesth* 2009; 23:886–892
- Sidebotham D, McGeorge A, McGuinness S, et al: Extracorporeal membrane oxygenation for treating severe cardiac and respiratory failure in adults: Part 2—technical considerations. *J Cardiothorac Vasc Anesth* 2010; 24:164–172
- Extracorporeal Life Support Organization: ELSO Guidelines for Training and Continuing Education of ECMO Specialists. Available at: http://www.else.org/Portals/0/IGD/Archive/FileManager/97_000963d6cuserssh yerdocu mentse lso guidelines esfortrainingan dcontinuing educatione cmospe cialists.pdf. Accessed September 26, 2018
- Extracorporeal Life Support Organization: ELSO Guidelines for ECMO Centers. Available at: <https://www.else.org/Portals/0/IGD/Archive/FileManager/faf3f6a3c7cuserssh yerdocu mentse lso guidelines esecmocentersv1.8.pdf>. Accessed December 12, 2018
- Muratore S, Beilman G, John R, et al: Extracorporeal membrane oxygenation credentialing: where do we stand? *Am J Surg* 2015; 210:655–660.e2
- Humphrey-Murto S, Varpio L, Gonsalves C, et al: Using consensus group methods such as Delphi and Nominal Group in medical education research. *Med Teach* 2017; 39:14–19
- Accreditation Council for Graduate Medical Education: Common Program Requirements. Available at: <https://www.acgme.org/What-We-Do/Accreditation/Common-Program-Requirements>. Accessed January 8, 2018
- Liaison Committee for Graduate Medical Education: Functions and structure of a medical school: standards for accreditation of medical education program leading to the M.D. degree. Available at: <http://lcme.org/publications/>. Accessed January 8, 2019
- Brogan T-V, L L, Lorusso R, et al (Eds.): Extracorporeal Life Support: The ELSO Red Book. 5th edition ed. Ann Arbor, Michigan: Extracorporeal Life Support Organization; 2017
- Brogan T-V, A G, Ellis W-C, et al (Eds.): ECMO Specialist Training Manual. 4th Edition ed. Ann Arbor, Michigan: Extracorporeal Life Support Organization; 2017

21. Sanchez-Glanville C, Brindle ME, Spence T, et al: Evaluating the introduction of extracorporeal life support technology to a tertiary-care pediatric institution: Smoothing the learning curve through interprofessional simulation training. *J Pediatr Surg* 2015; 50:798–804
22. Cook MR, Badulak J, Çoruh B, et al: Fellowship training in extracorporeal life support: Characterization and educational needs assessment. *J Crit Care* 2018; 46:159–161
23. Chan SY, Figueroa M, Spentzas T, et al: Prospective assessment of novice learners in a simulation-based extracorporeal membrane oxygenation (ECMO) education program. *Pediatr Cardiol* 2013; 34:543–552
24. Fouilloux V, Gran C, Guervilly C, et al: Impact of education and training course for ECMO patients based on high-fidelity simulation: a pilot study dedicated to ICU nurses. *Perfusion* 2018;267659118789824
25. Zakhary BM, Kam LM, Kaufman BS, et al: The utility of high-fidelity simulation for training critical care fellows in the management of extracorporeal membrane oxygenation emergencies: A randomized controlled Trial. *Crit Care Med* 2017; 45:1367–1373
26. Burkhart HM, Riley JB, Lynch JJ, et al: Simulation-based postcardiotomy extracorporeal membrane oxygenation crisis training for thoracic surgery residents. *Ann Thorac Surg* 2013; 95:901–906
27. Extracorporeal Life Support Organization: ELSO and ELSO Endorsed Courses/Workshops. Available at: <https://www.else.org/Events/ELSOandELSOEndorsedCoursesWorkshops.aspx>. Accessed January 8, 2019
28. The Alfred ICU: Alfred ICU Courses. Available at: <https://www.alfredicu.org.au/courses>. Accessed January 6 2019
29. Royal Papworth Hospital NHS: Royal Papworth ECMO Courses. Available at: <https://royalpapworth.nhs.uk/health-professionals/papworth-professional-development/critical-care-courses/ecmo-courses>. Accessed January 6, 2019
30. Extracorporeal Life Support Organization: Cannulation Workshop. Available at: <https://www.else.org/Membership/Courses/May2019Cannulation.aspx>. Accessed January 7, 2019
31. International Fluid Academy: IFAD ECMO Course. Available at: <https://www.fluidacademy.org/blog-ifad-2018/item/2nd-ecmo-course.html>. Accessed January 7, 2019
32. Hospital Internacional de Colombia: Curso ELSO LATAM de ECMO Veno-Arterial y Asistencia Ventricular Temporal. Available at: <http://www.fcv.org/site/curso-elseo-latam/estrategias-de-aprendizaje/estrategias-de-aprendizaje>. Accessed January 7, 2019
33. Society of Critical Care Medicine: ECMO Management Workshop. Available at: <http://www.cvent.com/events/2018-ecmo-management-workshop/event-summary-f1b6d70a79e-3469990c4346db796088e.aspx>. Accessed January 7, 2019
34. TCS-ECMO: ECMO DIPLOMA – TCS-ECMO. Available at: <https://www.paris-tcsecmo.org/ecmo-diploma/>. Accessed March 14, 2019
35. Reed DA: Nimble approaches to curriculum evaluation in graduate medical education. *J Grad Med Educ* 2011; 3:264–266
36. Hutchinson L: Evaluating and researching the effectiveness of educational interventions. *BMJ* 1999; 318:1267–1269
37. Kern DE, EBB, Thomas PA, et al: Curriculum Development for Medical Education: A Six Step Approach. Baltimore, MD, JHU Press, 1998
38. Phillips AW, Smith SG, Straus CM: Driving deeper learning by assessment: An adaptation of the revised bloom's taxonomy for medical imaging in gross anatomy. *Acad Radiol* 2013; 20:784–789
39. Jefferson: ECMO Training Program. Available at: <https://www.jefferson.edu/university/emerging-health-professions/programs/ecmo-training.html>. Accessed 6 January 2019,
40. Geisinger: Geisinger ECMO Conference. Available at: <https://cmetracker.net/GEISINGERCME/Catalog?EventID=126985>. Accessed January 6, 2019
41. Mayo Clinic: Mayo Clinic Extracorporeal Membrane Oxygenation (ECMO) Symposium 2018. Available at: <https://ce.mayo.edu/critical-care/content/mayo-clinic-extracorporeal-membrane-oxygenation-ecmo-symposium-2018>. Accessed January 6, 2019
42. Innovative ECMO: Courses. Available at: <https://www.innovativeecmo.com/services/ecmo-education/>. Accessed January 4, 2019
43. ECMO Advantage: Courses. Available at: <https://ecmoadvantage.com/upcoming-courses/>. Accessed January 6, 2019
44. Society of Critical Care Medicine: Critical Care Congress. Available at: <https://www.sccm.org/Education-Center/Annual-Congress/Past-and-Future>. Accessed January 6, 2019
45. Society of Thoracic Surgeons: ECMO Symposium. Available at: <https://www.sts.org/meetings/calendar-of-events/ecmo-symposium>. Accessed January 6, 2019
46. South West Asia and Africa Chapter of ELSO: SWAAC ELSO Workshop. Available at: <http://swaacelso2019.com/workshop/>. Accessed January 6, 2019
47. American Thoracic Society: ATS International Conference. Available at: <http://www.abstractsonline.com/pp8/#!/4499/session/300>. Accessed January 6, 2019
48. The Australian and New Zealand Intensive Care Society: Asia Pacific Intensive Care Forum: SG-ANZICS 2019, Pre-forum workshops. Available at: <http://sg-anzics.com/page/pre-forum-workshops-master-classes.html>. Accessed January 12, 2019
49. Extracorporeal Life Support Organization: Advanced VV ECMO Workshop. Available at: <https://www.else.org/Membership/Chapters/SCCMWorkshopSanDiego2019.aspx> Accessed January 7, 2019
50. Bellezzo J, Shinar Z, Weingart S: EDECMO Resuscitator-Initiated Extracorporeal Life Support and Enhanced CPR. Available at: <https://edecmo.org/>. Accessed December 11, 2018
51. INTUBATIEM: Pulsatio. Available at: <http://www.intubati.org/event-intubati/pulsatio-2019/>. Accessed January 7, 2019
52. Ruiz JG, Mintzer MJ, Leipzig RM: The impact of E-learning in medical education. *Acad Med* 2006; 81:207–212
53. Boulos MN, Maramba I, Wheeler S: Wikis, blogs and podcasts: A new generation of Web-based tools for virtual collaborative clinical practice and education. *BMC Med Educ* 2006; 6:41
54. Goldberg LR, Crocombe LA: Advances in medical education and practice: Role of massive open online courses. *Adv Med Educ Pract* 2017; 8:603–609
55. Liyanagunawardena TR, Williams SA: Massive open online courses on health and medicine: Review. *J Med Internet Res* 2014; 16:e191
56. Maryland.CCProject.com: ECMO Boot Camp. Available at: <http://maryland.ccproject.com/2016/12/03/ecmo-boot-camp-day-1/>. Accessed December 11, 2018
57. ECMO Educación: Soluciones en soporte de vida extracorpórea. Available at: <http://ecmoeducacion.mx/>. Accessed December 11, 2018
58. Dickstein M: ECMOed. Available at: <https://ecmoed.org/>. Accessed December 11, 2018
59. Nickson C: Everything ECMO. Available at: <https://lifeinthefastlane.com/everything-ecmo/>. Accessed December 11, 2018
60. European Chapter of ELSO: Euro-ELSO Webinars Available at: <https://www.euroelso.net/webinars/>. Accessed February 12, 2019
61. American Heart Association: Advanced Cardiovascular Life Support (ACLS), 2015 Guidelines ACLS Course Options. Available at: https://cpr.heart.org/AHA/ECC/CPRECC/Training/HealthcareProfessional/AdvancedCardiovascularLifeSupportACLS/UCM_473186_Advanced-Cardiovascular-Life-Support-ACLS.jsp. Accessed November 20, 2018
62. European Society of Cardiology: ESC - Endorsement Policy for Live Events in General Cardiology. Available at: https://www.escardio.org/static_file/Escardio/Education/Courses/ESC_Endorsement_Policy_Live_Events.pdf. Accessed November 20, 2018
63. The Royal College of Paediatrics and Child Health: Endorsement of educational programmes - application process. Available at: <https://www.rcpch.ac.uk/sites/default/files/generated-pdf/document/Endorsement-of-educational-programmes---application-process.pdf>. Accessed November 12, 2018
64. Ghaderi I, Fu M, Schwarz E, et al; SAGES Continuing Education Committee: SAGES framework for Continuing Professional Development (CPD) courses for practicing surgeons: The new SAGES course endorsement system. *Surg Endosc* 2017; 31:3827–3835
65. Soar J, Donnino MW, Maconochie I, et al; ILCOR Collaborators: 2018 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations summary. *Circulation* 2018; 138:e714–e730

66. Gruppen LD, Grum CM, Fincher RM, et al: Multi-site reliability and validity of a diagnostic pattern-recognition knowledge-assessment instrument. *Acad Med* 1996; 71:S65–S67
67. Voduc N, Dudek N, Parker CM, et al: Development and validation of a bronchoscopy competence assessment tool in a clinical setting. *Ann Am Thorac Soc* 2016; 13:495–501
68. Institute for Credentialing Excellence: About ICE. Available at: <http://www.credentialingexcellence.org/p/cm/ld/fid=32>. Accessed December 6, 2018
69. 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; 190:488–496