ORIGINAL RESEARCH

An International Survey of Extracorporeal Membrane Oxygenation Education and Credentialing Practices

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ABSTRACT

Background: The use of extracorporeal membrane oxygenation (ECMO) has grown rapidly over the past decades because of evolving indications, advances in circuit technology, and encouraging results from modern trials. Because ECMO is a complex and highly invasive therapy that requires a multidisciplinary team, optimal education, training, and credentialing remain a challenge.

Objective: The primary objectives of this study were to investigate the prevalence and application of ECMO education and ECMO practitioner credentialing at ECMO centers globally. In addition, we explored differences among education and credentialing practices in relation to various ECMO center characteristics.

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Methods: We conducted an observational study of ECMO centers worldwide using a survey querying participants in two major domains: ECMO education and ECMO practitioner credentialing. Of note, the questionnaire included ECMO program characteristics, such as type and size of hospital and ECMO experience and volume, to explore the association with the two domains.

Results: A total of 241 (32%) of the 732 identified ECMO centers responded to the survey, representing 41 countries across the globe. ECMO education was offered at 221 (92%) of the 241 centers. ECMO education was offered at 105 (98.0%) high–ECMO volume centers compared with 136 (87.5%) low–ECMO volume centers ($P = 0.005$). Credentialing was established at 101 (42%) of the 241 centers. Credentialing processes existed at 52 (49.5%) high–ECMO volume centers compared with 51 (37.5%) low–ECMO volume centers ($P = 0.08$) and 101 (49.3%) Extracorporeal Life Support Organization centers compared with 1 (2.7%) non–Extracorporeal Life Support Organization center ($P < 0.001$).

Conclusion: We found significant variability in whether ECMO educational curricula are offered at ECMO centers. We also found fewer than half of the ECMO centers surveyed had established credentialing programs for ECMO practitioners. Future studies that assess variability in outcomes among centers with and without standardized educational and credentialing practices are needed.

Keywords:
extracorporeal membrane oxygenation; education; training; simulation; credentialing

Extracorporeal membrane oxygenation (ECMO) is a form of mechanical respiratory and/or circulatory support used to manage patients with refractory respiratory and/or cardiac failure. The use of ECMO has grown rapidly over the past decades because of evolving indications, advances in circuit technology, and encouraging results from modern trials (1–7). Although there has been a significant increase in hospitals reporting data to the Extracorporeal Life Support Organization (ELSO) registry, the number of hospitals providing ECMO globally remains unknown (8). Despite this increase in utilization, availability, and experience, there remains wide variability in global outcomes and complications (8, 9).

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This article has a related editorial.

This article has a data supplement, which is accessible at the Supplements tab.

Because ECMO is a complex and highly invasive therapy that requires a multidisciplinary team (e.g., physicians, nurses, respiratory therapists, and perfusionists), optimal education, training, and credentialing remains a challenge. Founded in 1989, ELSO is a global nonprofit organization with four international chapters. In 2018, the ELSOed Taskforce, consisting of 40 healthcare practitioners with expertise in ECMO management and education, was created to describe the state of ECMO education and identify opportunities for standardization and collaboration (10). To sustain a global perspective, the taskforce consisted of members representing all ELSO chapters as well as a multidisciplinary group representing the different specialties and disciplines involved in ECMO care. Despite ECMO being widely used in intensive care units around the world, little is known about education and credentialing practices of ECMO centers.

The primary objectives of this study were to investigate the prevalence and application of ECMO education and of ECMO practitioner credentialing at ECMO centers globally. In addition, we set out to explore differences among education and credentialing practices in relation to ECMO center characteristics, such as hospital type, hospital size, ECMO experience, ECMO volume, and ELSO membership, with the hypothesis that significant variability exists in ECMO education and credentialling practices globally.

METHODS

This study, which was titled "Extracorporeal educational practices, results of an international survey," was approved as exempt from the Washington University Human Research Protection Office Institutional Review Board on October 29, 2020 (FWA00002284).

Survey

Survey design. A systemic approach was used to develop the survey questionnaire (11,12). Seven members of the ELSOed Research Workgroup developed the initial questionnaire. Using in-person focus group sessions, the workgroup identified two major domains, ECMO education and ECMO practitioner credentialing, to address the research questions. Of note, the questionnaire included ECMO program characteristics, such as type and size of hospital and ECMO experience and volume, to explore the association with the two domains. Within the education domain, the questionnaire evaluated the role of different educational modalities, such as in-person or online didactics and hands-on training, including water drills and simulations. Within the credentialing domain, the questionnaire evaluated credentialing requirements for ECMO practitioners, including maintenance of credentialing and barriers to credentialing. Furthermore, using a 5-point Likert scale, we assessed the perceived importance of didactic and hands-on education as well as perspectives on minimum competency requirements for ECMO credentialing in the future.

The questionnaire was reviewed by the remaining four members of the ELSOed Research Workgroup for validation. First, it was pilot tested by the group to ensure clarity, relevance, and flow. Subsequently, it underwent clinical sensibility testing for comprehensiveness and face validity using a standardized assessment approach. Each step was followed by questionnaire revision with subsequent repetition until all concerns were addressed. A total of five questions were removed from the

questionnaire because of redundancy or ambiguity. The final questionnaire consisted of 10 questions on demographics, 15 in the education domain, and 10 in the credentialing domain.

Survey sample. Global ECMO centers were identified using two approaches. First, we queried the ELSO registry for registered ECMO centers. A total of 578 ELSO ECMO centers were identified from the database. Second, to identify ECMO centers not registered with the ELSO database, ECMO clinicians were identified using targeted campaigns on social media platforms (Twitter, Facebook, LinkedIn, and Instagram) and past ELSO conference participant registries. A preliminary survey (*see* data supplement) was sent to all identified ECMO clinicians to assess for interest in study enrollment, and an additional 154 non-ELSO centers were identified. A total of 732 ECMO centers remained after crosschecking for duplication.

Survey administration. The survey was hosted on Google Forms (Alphabet Inc.; www.docs.google.com/forms) and distributed in June 2019. Only one survey was collected per program, and we did not incentivize participation. To maximize the response rate, an electronic reminder was sent to all participants at 1-week intervals for 3 weeks. When multiple responses were received from the same institution, we only included the survey from the first respondent.

Statistical Analysis

Statistical analyses and figure generation were performed using R and RStudio version 1.4.1106 (2009–2021 RStudio, PBC). Qualitative variables are reported as number and percentage, and quantitative variables are reported as median and interquartile range unless otherwise specified. To assess the educational and credentialing practices in general, we first performed a descriptive analysis of the frequency and percentage of all responses. We then performed comparative analyses based on the respondents' institution type, institution volume, ELSO membership, ECMO volume, and ECMO experience to assess for any differences in either educational or credentialing practices based on these distinguishing criteria. To aid in the comparative analysis, 500–hospital bed volume was used to categorize large institution size, a cutoff of 30 annual ECMO runs was used to identify centers with high ECMO volume, and 5 years of ECMO experience was used to identify centers with long ECMO experience. Mann-Whitney *U* test was used when comparing continuous variables and chi-square test for categorical variables. A *P* value of <0.05 was considered statistically significant.

RESULTS

ECMO Program Characteristics

A total of 241 (32%) of the 732 identified ECMO centers responded to the survey, representing 41 countries across the globe and all six inhabited continents (Figure 1). One hundred forty-four (60%) of the centers were from North America, 53 (22%) from Europe, 24 (11%) from Asia, 8 (3%) from South America, 8 (3%) from Australia/New Zealand, and 2 (1%) from Africa, matching the global distribution of ECMO centers within the ELSO registry. Respondents included 87 nurses (36%), 32 perfusionists (15%), 24 respiratory specialists (10%), 22 intensivists (9%), 20 anesthesiologists (8%), 12 nurse practitioners (5%), 12 cardiac surgeons (5%), and 29 others (12%). A total of 205 (85%)

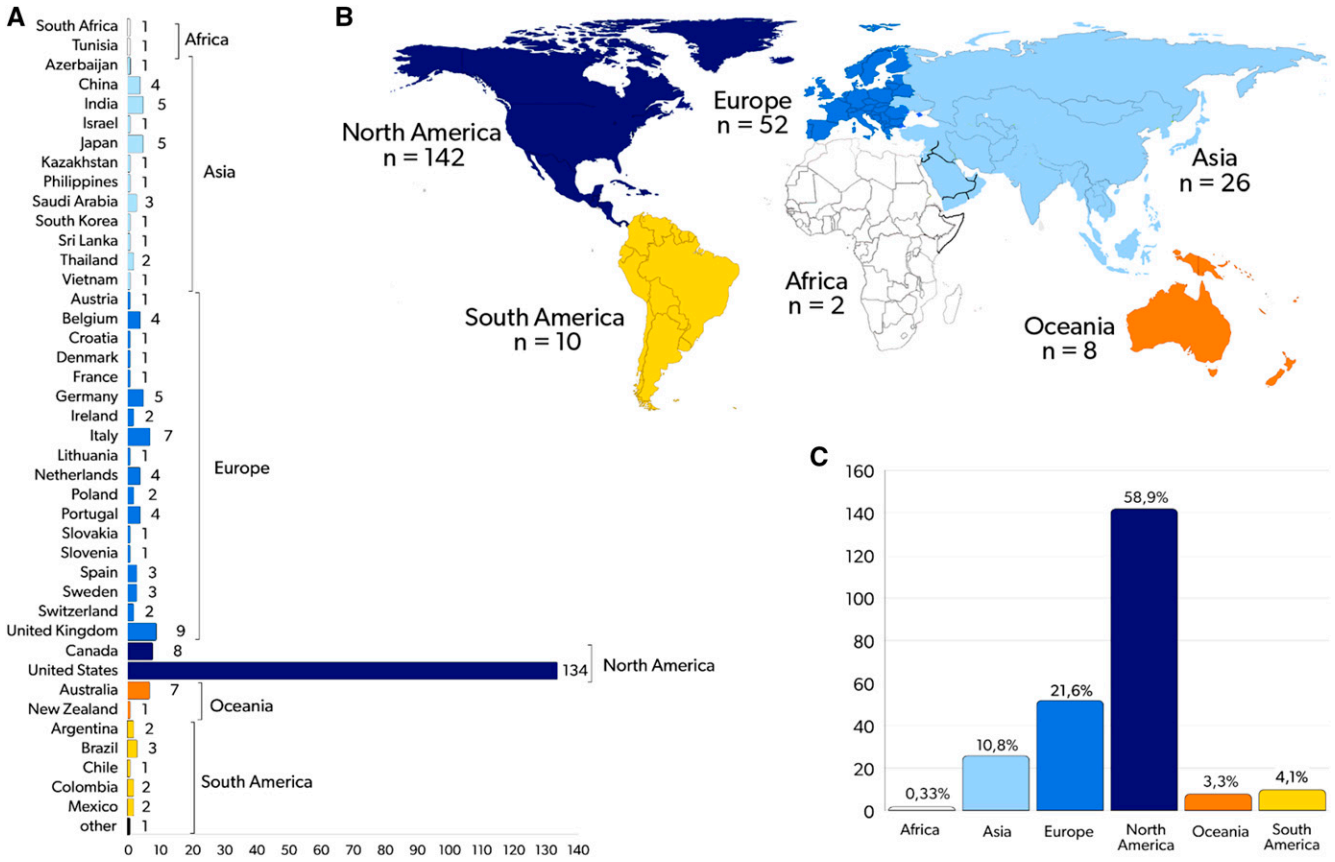

Figure 1. Geographical distribution of extracorporeal membrane oxygenation centers participating in the survey. (*A*) Response count by countries. (*B*) Geographic display and response count by continents. (*C*) Response count in percentage by continents.

of the ECMO centers were ELSO centers. Table 1 summarizes the ECMO centers' demographics and characteristics.

ECMO Education

Among survey respondents, ECMO education was offered at 221 (92%) of the 241 centers. Education was offered at 105 (98.0%) high–ECMO volume centers compared with 136 (87.5%) low–ECMO volume centers ($P = 0.005$), 198 (96.6%) ELSO centers compared with 23 (63.9%) non-ELSO centers ($P < 0.001$), and 135 (93.1%) academic institutions compared with 87 (90.6%) nonacademic institutions ($P = 0.64$). Additional data on education offering when compared by other center characteristics are listed in Table 2.

ECMO education delivered through both didactics and simulation was perceived as very important or extremely important by the majority (95%) of respondents. No center reported didactics or simulation education as not important. High–ECMO volume centers attached a higher importance to simulation-based training versus low–ECMO volume centers. There was a significant difference in perceived importance of both didactics and simulation education among ELSO compared with non-ELSO centers for importance of didactics and simulation education (Figure 2).

ECMO volume, regular interval simulations, clinical protocol developments, and quality improvement initiatives were deemed more important to maintain ECMO competency

Table 1. Baseline characteristic of participating extracorporeal membrane oxygenation centers

Demographics and Characteristics	*n* (%)
ECMO Program	
Adult only	124 (51)
Pediatric only	4 (2)
Neonate only	7 (3)
Mixed	106 (44)
ECMO configuration	
V–A and V–V	229 (95)
V–A only	5 (2)
V–V only	6 (3)
Annual ECMO volume	
>30 ECMO	105 (44)
<30 ECMO	131 (54)
Total hospital bed count	
0–300 beds	31 (13)
301–500 beds	67 (28)
>500 beds	100 (41)
ECMO center experience, yr	
0–2	14 (6)
3–5	44 (18)
6–10	45 (19)
11–20	56 (23)
>20	81 (34)
Registered ELSO center	
Yes	205 (85)
No	36 (15)

Definition of abbreviations: ECMO = extracorporeal membrane oxygenation; ELSO = Extracorporeal Life Support Organization; V–A = veno-arterial; V–V = veno-venous.

than attendance at journal clubs, attendance at national ECMO conferences, or conducting ECMO research. Compared with respondents from lower–ECMO volume centers, those from high–ECMO volume centers attached lower importance to involvement in writing or publishing ECMO guidelines and protocols ($P = 0.017$) but higher importance to membership in scientific societies ($P = 0.04$). Furthermore,

Table 2. Educational practices by extracorporeal membrane oxygenation center characteristics

	Academic Institution			Large Hospital Size (>500)			ELSO Membership			High ECMO Volume (>30/yr)			ECMO Experienced (>5 yr)		
	Yes (*n* = 145)	No (*n* = 96)	*P* Value	Yes (*n* = 141)	No (*n* = 100)	*P* Value	Yes (*n* = 205)	No (*n* = 36)	*P* Value	Yes (*n* = 105)	No (*n* = 136)	*P* Value	Yes (*n* = 182)	No (*n* = 59)	*P* Value
Education															
Offered, *n* (%)	135 (93.1)	87 (90.6)	0.64	126 (89.4)	96 (96)	0.11	198 (96.6)	23 (63.9)	0.01	103 (98)	119 (87.5)	0.05	172 (94.5)	50 (84.7)	0.11
Perceived importance of education, median (IQR)															
Didactic	5 (5–5)	5 (4–5)	0.39	5 (4–5)	5 (5–5)	0.48	5 (5–5)	5 (4–5)	0.02	5 (5–5)	5 (4–5)	0.45	5 (5–5)	5 (4–5)	0.05
Simulation	5 (5–5)	5 (5–5)	0.71	5 (5–5)	5 (5–5)	0.32	5 (5–5)	5 (4–5)	0.05	5 (5–5)	5 (4–5)	0.02	5 (5–5)	5 (4–5)	0.30
Factors important to maintain competency, median (IQR)															
Number of ECMO patients	5 (4–5)	5 (4–5)	0.72	5 (4–5)	5 (4–5)	0.38	5 (4–5)	5 (4–5)	0.04	5 (4–5)	5 (4–5)	0.15	5 (4–5)	5 (4–5)	0.74
Simulation	5 (4–5)	5 (4–5)	0.65	5 (4–5)	5 (4–5)	0.32	5 (4–5)	5 (4–5)	0.04	5 (4–5)	5 (4–5)	0.23	5 (4–5)	5 (4–5)	0.55
Guidelines/protocols adherence	5 (4–5)	5 (4–5)	0.47	5 (4–5)	5 (4–5)	0.80	5 (4–5)	4 (3.25–5)	0.04	4 (4–5)	5 (4–5)	0.01	5 (4–5)	5 (4–5)	0.39
Journal club	3 (2–4)	3 (3–4)	0.05	3 (2–4)	3 (2–4)	0.36	3 (2–4)	3 (2.–4)	0.80	3 (2–4)	3 (2–4)	0.25	3 (2–4)	3 (3–4)	0.63
Quality assurance	5 (4–5)	4.5 (4–5)	0.95	5 (4–5)	4 (4–5)	0.35	5 (4–5)	4 (4–5)	0.90	5 (4–5)	5 (4–5)	0.19	5 (4–5)	5 (4–5)	0.59
Attendance at ECMO conferences	4 (3–4)	4 (3–5)	0.93	4 (3–5)	4 (3–4)	0.20	4 (3–4)	4 (3–5)	0.81	4 (3–4)	4 (3–5)	0.37	4 (3–4)	4 (3–5)	0.73
Research	4 (3–4)	4 (3–4)	0.62	4 (3–4)	4 (2–4)	0.16	4 (3–4)	4 (3–5)	0.30	4 (3–4)	4 (3–4)	0.34	4 (3–4)	4 (3–4)	0.38
Society membership	3 (2–4)	3 (2–4)	0.25	3 (3–4)	3 (2–4)	0.04	3 (2–4)	4 (3–4)	0.66	3 (2–4)	3 (2–4)	0.10	3 (2–4)	3 (2–5)	0.25

Definition of abbreviations: ECMO = extracorporeal membrane oxygenation; ECMO experienced center = center with ECMO experience of 5 or more years; ELSO = Extracorporeal Life Support Organization; high ECMO volume = center with annual ECMO volume of 30 or more runs; high-volume center = center with capacity of 500 beds or more.
P value determined by chi-square test for categorical variables and Mann-Whitney *U* test for continuous variables.

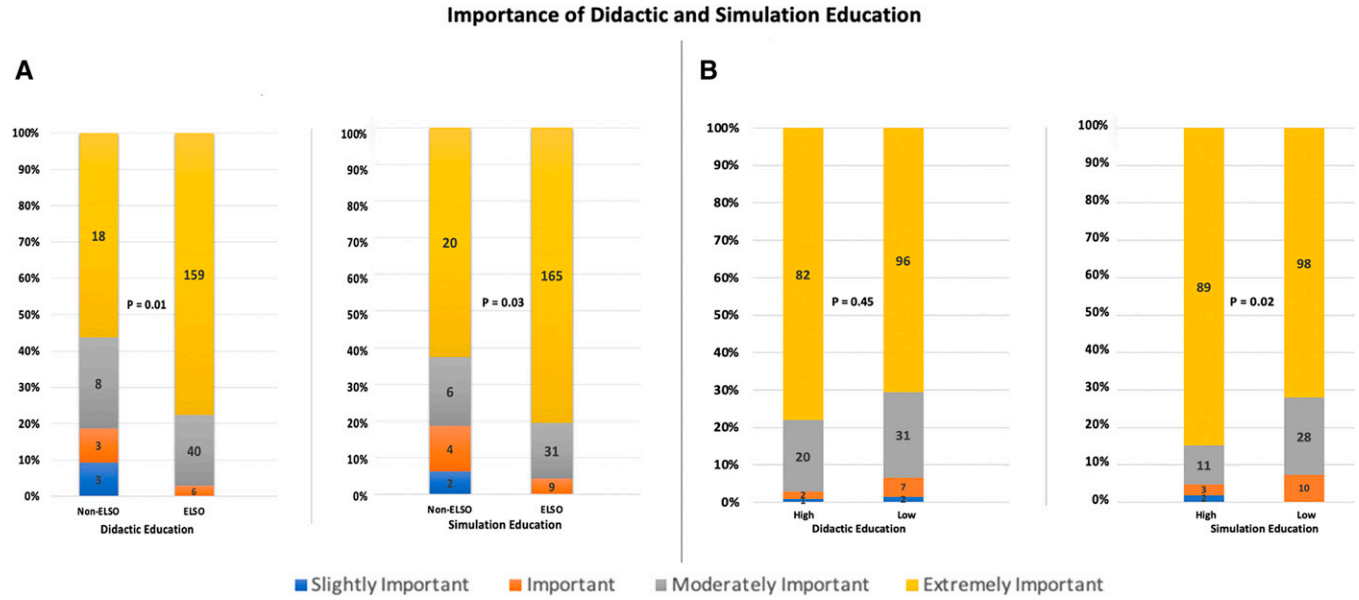

Figure 2. (*A*) Perceived importance of didactic and simulation extracorporeal membrane oxygenation (ECMO) education among Extracorporeal Life Support Organization (ELSO) and non-ELSO centers. (*B*) Perceived importance of didactic and simulation ECMO education among high and low ECMO volume centers.

respondents from ELSO centers reported higher importance to the number of ECMO patients treated, regular skills and simulation-based training, and involvement in the ECMO guidelines and protocols compared with those from non-ELSO centers ($P = 0.048$, 0.048, and 0.049, respectively). Most centers either agreed or strongly agreed with the usefulness of ELSO resources such as the Red Book (204 [84.6%]), Specialist Training Manual (193 [80%]), and online guidelines (192 [79.7%]).

Credentialing Practices

Among survey respondents, 101 (42%) centers have established credentialing processes for ECMO practitioners. Credentialing processes existed at 52 (49.5%) high–ECMO volume centers compared with 51 (37.5%) low–ECMO volume centers ($P = 0.08$), 101 (49.3%) ELSO centers compared with 1 (2.7%) non-ELSO center ($P < 0.001$), and 60 (41.4%) academic institutions compared with 43 (44.8%) nonacademic institutions ($P = 0.69$). Additional data on credentialing when compared by other demographics are listed in Table 3. For centers with credentialing practices, responsibility for credentialing fell under the ECMO program director (51%) or occurred at the hospital level (30%). There were variable frequencies for recredentialing depending on the type of ECMO practitioner. Recredentialing was required every 2–5 years for physicians (52.6%) and every year for nurses or nurse practitioners (83.3%), perfusionists (73.5%), and respiratory therapists (85.4%).

Barriers to Credentialing

Lack of funding, infrastructure, and time were identified by respondents as the main barriers to ECMO credentialing. Low-volume centers reported ECMO volume, training expertise, and simulation expertise to be a greater barrier to ECMO credentialing relative to high-volume centers (Table 3). Similarly, centers with longer ECMO experience attached higher

Table 3. Credentialing practices by extracorporeal membrane oxygenation center characteristics

	Academic Institution			Large Hospital Size (>500)			ELSO Membership			High ECMO Volume (>30/yr)			ECMO Experience (>5 yr)		
	Yes (*n* = 145)	No (*n* = 96)	*p* Value	Yes (*n* = 141)	No (*n* = 100)	*p* Value	Yes (*n* = 205)	No (*n* = 36)	*p* Value	Yes (*n* = 105)	No (*n* = 136)	*p* Value	Yes (*n* = 182)	No (*n* = 59)	*p* Value
Credentialing practices															
Present, *n* (%)	60 (41.4)	43 (44.8)	0.69	60 (42.5)	43 (43)	1	101 (49.3)	1 (2.7)	0.001	52 (49.5)	51 (37.5)	0.08	79 (43.4)	46 (40.6)	0.8
Perceived barriers, median (IQR)															
Lack of funding	3 (2–4)	3 (2–4)	0.39	3 (2–4)	3 (2–4)	0.24	3 (2–4)	4 (3–5)	0.04	3 (2–4)	3 (2–4)	0.41	3 (2–4)	3 (2–4)	0.69
Lack of infrastructure	3 (2–4)	3 (2–4)	0.89	3 (2–4)	3 (1–4)	0.09	3 (2–4)	3 (2–4)	0.24	3 (2–4)	3 (2–4)	0.36	3 (2–4)	3 (2–4)	0.8
Lack of initiative	2 (1–4)	3 (2–4)	0.17	3 (2–4)	2 (1–3)	0.24	2 (1–3)	3 (2–4)	0.01	2 (1–3)	3 (2–4)	0.01	3 (2–4)	2 (2–3)	0.27
Lack of time	3 (2–4)	3 (2–4)	0.73	3 (2–4)	3 (2–4)	0.16	3 (2–4)	3 (2–4)	0.66	3 (1–4)	3 (2–4)	0.58	3 (2–4)	3 (2–4)	0.6
Insufficient ECMO volume	2 (1–3)	2 (1–4)	0.04	2 (1–3)	2 (1–3)	0.88	2 (1–3)	2 (1–4)	0.15	1 (1–2)	3 (2–4)	0.01	1 (1–4)	3 (2–4)	0.01
Insufficient training experience	2 (1–3)	2 (1–3)	0.09	2 (1–3)	2 (1–3)	0.82	2 (1–3)	3 (2–4)	0.01	1 (1–2)	3 (2–3)	0.01	2 (1–3)	3 (2–3)	0.01
Insufficient simulation expertise	2 (1–3)	2 (1–3)	0.04	2 (1–3)	2 (1–3)	0.6	2 (1–3)	3 (2–4)	0.01	1 (1–2)	2 (2–3)	0.01	2 (1–3)	2 (2–3)	0.01

For definition of abbreviations, *see* Table 2.
P value determined by chi-square test for categorical variables and Mann-Whitney *U* test for continuous variables.

importance to ECMO volume, training experience, and simulation expertise than centers with shorter ECMO experience. In addition, respondents from nonacademic centers attached slightly higher importance to ECMO volume, training experience, and simulation expertise. There were no other differences in the perceived barriers to credentialing when compared by ECMO center characteristics. Non-ELSO centers perceived lack of funding, training expertise, and simulation expertise to be a greater barrier to ECMO credentialing compared with ELSO centers (Table 3).

Credentialing Requirement

Respondents identified knowledge tests, practical tests, and simulation training as being of greater importance than ECMO volume or research as minimum requirements for ECMO credentialing; 54% of centers believed attendance at an ELSO or ELSO-endorsed ECMO course should be a part of the clinician credentialing requirement.

DISCUSSION

As the first international study evaluating global ECMO education and credentialing practices, the primary findings are: *1*) there is significant variation in ECMO educational offerings among high–ECMO volume centers compared with low-volume centers as well as ELSO and non-ELSO centers; *2*) fewer than half of ECMO centers have established credentialing programs for ECMO practitioners; and *3*) lack of funding, infrastructure, and time are the primary barriers to credentialing.

Given the rapid growth of ECMO, our findings are important and timely. ECMO remains a highly complex and resource-intensive intervention requiring specialized knowledge, quick decision making, and interdisciplinary teamwork. Variations in educational opportunities at high-volume compared with low-volume centers as well as ELSO and non-ELSO centers were anticipated, but the difference in the perceived importance of education was unexpected. Whether this difference reflects greater accessibility to educational resources and better program infrastructure or is a consequence of the greater perceived importance of ECMO education is unclear. Our study's findings are consistent with prior reports of varied educational practices in the United States (13–15). Recently, Schwartz and colleagues reported that coordinating best ECMO practices through education reduced complications and improved rates of ECMO weaning and survival to discharge, without additional cost, across ECMO programs within a healthcare system (16). Similarly, Anderson and colleagues demonstrated that ECMO education improved cognitive, technical, and behavioral skills in both ECMO simulation and real-time practice (17). In addition, Burkhart and colleagues documented improved confidence scores and crisis management in a simulation-based ECMO training program (18). It is likely that improving access to critical educational resources and collaboration among ECMO centers could facilitate improved educational initiatives and possibly ECMO outcomes (19–23).

Certification is a vital process for healthcare practitioners to ensure that a minimum level of education or training with associated competency has been met. In contrast with licensure, which is a statutory or regulatory requirement, certification is a voluntary process that is meant to confer recognition of clinical excellence. We found that fewer than half of ECMO centers had established

credentialing programs, with significantly fewer credentialing practices at non-ELSO compared with ELSO centers. Our study's findings are consistent with prior reports of varied credentialing practices (24). At the hospital level, several barriers to credentialing, including lack of funding, infrastructure, and time, were identified. Although these hurdles pose significant challenges to overcome, ELSO recently outlined a standardized ECMO education and practitioner certification pathway in hopes of facilitating hospital-level credentialing of ECMO practitioners (25).

Limitations

The present study should be interpreted in the context of certain limitations. First, although the study sample primarily reflects responses from U.S. and European centers, the response rate matches the global distribution of ECMO centers within the ELSO registry. Second, every effort was made to include both ELSO and non-ELSO centers. Despite this, there are likely many institutions practicing ECMO that are not represented, and we recognize that a larger sample of non-ELSO centers may yield different results. Finally, given the lack of standardization for ECMO education and credentialing, individual interpretation of the terms could vary among centers based on local regulations.

Conclusions

Our study identifies important deficits in ECMO education and credentialing practices around the world. Development of appropriate educational standards for ECMO practice has the potential to decrease care variability and improve patient outcomes. A standard educational training pathway and certification process presents a challenge to encompass the varied practices worldwide. There is a clear need for the development of a standardized ECMO education and training pathway to achieve a minimum level of competency. Future studies that assess the association between ECMO center outcomes and the presence or absence of standardized educational and credentialing practices would be welcomed.

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