

SERVICE EVALUATION

Clinicians' Knowledge, Confidence and Skills: A Retrospective Evaluation of an Interdisciplinary Extracorporeal Membrane Oxygenation Simulation Workshop

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ABSTRACT

Background: Extracorporeal membrane oxygenation (ECMO) is a complex, high-risk therapy requiring interdisciplinary expertise and structured education to optimise patient outcomes. International experts recommend standardised, structured ECMO education, incorporating simulation, to support competency across clinician groups.

Aim: To evaluate changes in intensive care unit (ICU) clinicians' self-reported ECMO knowledge, confidence and skills after participation in a 1-day ECMO interdisciplinary simulation workshop.

Study Design: A retrospective study of pre- and post-survey evaluation data from ECMO simulation workshops delivered at a metropolitan quaternary adult hospital (2014–2019). Participants (registered nurses, medical officers, perfusionists and physiotherapists) self-rated their knowledge of veno-venous (VV) and veno-arterial (VA) ECMO, confidence in providing regular care and emergency management of ECMO in the ICU, and ECMO circuit problem-solving skills on Likert-type scales [1 = lowest (worst possible/most negative), 9 = highest (best possible/most positive)]. Paired *t*-tests compared pre- and post-scores and were stratified by clinician group. Free-text response data were thematically analysed.

Results: Matched pre- and post-workshop evaluations were analysed ($n = 275$) across 20 ECMO simulation workshops (99% response rate). Most participants (65%) were self-rated novices at baseline. Significant improvements across all individual domains ($p < 0.001$) were measured: Clinicians' self-rated knowledge of VV-ECMO (3.63–6.59; mean change 2.95, 95% CI, 2.78–3.12) and VA-ECMO (3.44–6.41; mean change 2.97, 95% CI, 2.80–3.14) as well as confidence in routine ECMO management (3.24–6.31; mean change 3.07, 95% CI, 2.88–3.25) and emergency management (2.42–6.09; mean change 3.68, 95% CI, 3.49–3.87) plus ECMO circuit skills (2.41–6.10; mean change 3.69, 95% CI, 3.50–3.89). Registered nurses demonstrated the greatest improvements in most domains. Themes corroborated workshop effectiveness.

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Conclusions: These findings support incorporating interdisciplinary, simulation-based ECMO education into credentialing and continuing education frameworks, particularly for nurses. Future research should examine how workshop participation translates into sustained learning retention, meaningful changes in clinical practice and improved patient-centred outcomes.

Relevance to Clinical Practice: The findings indicate that the single-day, simulation-based ECMO workshop improved ICU clinicians' self-reported ECMO knowledge, confidence and skill, particularly in managing emergencies and circuit-related complications. All workshop domains were considered appropriate for nurses' ECMO learning. The workshop's interdisciplinary format supports its inclusion in local ECMO credentialing pathways, alongside supervised clinical practice and ongoing education.

1 | Introduction

Extracorporeal membrane oxygenation (ECMO) is a widely used supportive and rescue therapy for select patients with refractory cardiac and/or respiratory failure [1]. Safe ECMO delivery requires advanced technology, vigilant monitoring and timely management of complications [2]. In Australia, our hospital was part of a global vanguard of healthcare centres demonstrating ECMO to be safe and viable with a lower than expected mortality from Acute Respiratory Distress Syndrome (ARDS) during the 2009 novel Influenza A (H1N1) virus pandemic [3]. Resources within our Australian home state of New South Wales (NSW) were stretched in response to the pandemic, particularly for the two ICUs offering ECMO retrieval services for patients in extremis [4, 5]. Following this period, there was a recognised need to broaden capacity within and beyond the existing NSW ECMO centres by upskilling ICU clinicians to develop local capability.

In 2010, when we first implemented our single-day ECMO simulation workshop open to both internal and external interdisciplinary participants, we were not aware of any other similar workshop in NSW. Interstate, the Alfred Hospital was recognised for developing and delivering a multi-day bi-annual workshop addressing many elements of ECMO care and management [6].

Coinciding with the need for ECMO expansion in NSW in response to the H1N1 pandemic, ECMO technology was fast-tracked to meet retrieval transport requirements [7]. These technological advances improved usability and incorporated the following: heparin-bonded circuits, smaller centrifugal pumps and more efficient, durable, non-leaking oxygenators [3]. These advances enhanced both transport [7] and in-hospital care of ECMO patients, demanding further vital upskilling of clinicians.

While ECMO care involved a skilled team of clinicians, in our ICU, one ECMO-accredited registered nurse was present at the bedside, with another ICU nurse to assist at ECMO commencement and during any period of patient instability [8]. In contrast, many North American ICUs employed the ECMO specialist model-of-care, whereby an ECMO Specialist would tend to all of the ECMO-related functions, and the ICU nurse would tend to the patient's care [9]. In response to our skilled team model-of-care and a clear and immediate need for rigorous education and credentialing within NSW and beyond, in 2010, we developed and offered our ECMO simulation workshop open to all ICU clinicians.

Since 2010, the global expansion of ECMO services has been accompanied by a broad stance that ICU clinicians (registered

nurses, medical officers, perfusionists and allied health professionals) require robust education and credentialing; a consensus that mirrors our experience [10–12]. The ECMO education literature describes a range of approaches, including structured nurse curricula, e-learning, short intensive training programmes and ongoing simulation-based refreshers [13–16]. A nurse-focused ECMO curriculum combining didactic content, simulation and written examinations significantly improved examination scores among critical care nurses new to ECMO [17]. Rapid interdisciplinary ECMO training programmes for large health systems and abbreviated single-day ECMO courses for medical officers and registered nurses have reported substantial gains in knowledge, confidence and skills [14, 18].

A modified-Delphi consensus has further defined adult essential ECMO skills across knowledge, technical tasks and attitudes, providing a foundation for ECMO education curricula [15]. Beyond ECMO-specific programmes, simulation-based education in ICUs has been shown to support procedural mastery, communication, teamwork and preparedness for high-risk, low-frequency events [13, 16]. It is widely recognised that interprofessional collaborative practice in healthcare strengthens health systems and improves patient outcomes [19]. Collectively, these findings support structured, interdisciplinary ECMO education as a key component of safe ECMO service implementation.

2 | Background

By 2008, our hospital had a site-specific ECMO policy and procedure, a local education programme and an internal process for testing clinician knowledge. During the H1N1 pandemic, we were a resource to low-volume ECMO centres [20]. Subsequently, from 2010 to 2019, we delivered a series of single-day interdisciplinary ECMO simulation workshops through our established simulation centre.

Between 2010 and 2013, standardised hospital education evaluation forms were used, requiring participants to rate the benefit of each workshop element from very beneficial to not beneficial at all. While these forms (and responses) justified the continuation of our workshop to hospital executives, they yielded limited meaningful feedback. The brief use of free-form evaluation documents similarly produced predominantly positive but non-actionable responses. This limitation prompted the development of a Likert-based pre- and post-survey self-assessment tool in 2014.

Impact Statements

- What is known about the topic
 - ECMO is a complex, high-risk therapy that requires structured education and interdisciplinary clinical expertise to support safe patient care.
 - Simulation-based ECMO education can improve ICU clinicians' knowledge, confidence, technical skills, communication, teamwork and preparedness for high-risk, low-frequency emergencies.
 - Existing ECMO education programmes vary in duration and professional focus, with limited evidence evaluating 1-day interdisciplinary workshops involving multiple ICU clinician groups.
- What this paper adds
 - A single-day interdisciplinary ECMO simulation workshop that included registered nurses, medical officers, perfusionists and physiotherapists was associated with significant immediate improvements in clinicians' self-reported knowledge, confidence and circuit management skills.
 - The greatest improvements were observed in confidence managing ECMO emergencies and circuit-related problems, with registered nurses reporting particularly strong gains across most domains.
 - The study demonstrates the feasibility and educational value of incorporating a pragmatic single-day interdisciplinary simulation workshop into local ICU ECMO credentialing and professional development pathways.

2.1 | Aim

To evaluate changes in ICU clinicians' self-reported ECMO knowledge, confidence and skills after participation in a single-day, interdisciplinary ECMO simulation workshop.

3 | Methods

3.1 | Study Design

We conducted a retrospective statistical and thematic analysis of routinely collected pre- and post-workshop evaluation data from interdisciplinary ECMO simulation workshops delivered 2014–2019. The study is reported (see [Supplement Cross Reporting](#)) using Equator CROSS reporting guidelines [21].

3.2 | Ethics Statement

The study used retrospective, de-identified educational quality-improvement data. St Vincent's Hospital Sydney Human Research Ethics Committee (HREC) confirmed that, as the study aligned with the NSW Health Quality Improvement guidelines, formal HREC approval was not required. Completion of pre- and post-workshop evaluation surveys implied consent to the quality improvement process.

3.3 | Setting

The workshops were delivered at a simulation centre within an adult quaternary metropolitan hospital that had an established interdisciplinary ICU simulation programme.

3.4 | Participants

Workshop attendees were ICU clinicians involved, or anticipated to be involved, in ECMO care, including registered nurses, medical officers, perfusionists and physiotherapists.

3.5 | ECMO Simulation Workshop Intervention

Each workshop was conducted over a single 8-h day and facilitated by an eight-member interdisciplinary faculty, comprising ICU nursing educators/clinicians, medical officers, perfusionists and the simulation department manager. The education was scaffolded, commencing with didactic VV- and VA-ECMO theoretical content, moving to circuit and console orientation and hands-on troubleshooting practice on two simulated ECMO circuits. The workshop then consolidated explicit and tacit knowledge in high-fidelity simulation scenarios, followed by immediate debriefing. While minor refinements occurred over time, the core workshop curriculum (see [File S1](#)) remained consistent in delivering these three integrated components: didactic teaching, hands-on circuit training and high-fidelity simulation.

Didactic sessions, delivered by ICU medical specialists, prepared participants for involvement in simulation by addressing ECMO principles, indications and contraindications, VV- and VA-ECMO configurations, anticoagulation, patient monitoring, weaning and complication management. While further pre-briefing was provided on context and expectations before each simulation session, these didactic sessions provided the prerequisite knowledge essential for subsequent practical involvement by participants [22].

Hands-on circuit training sessions were facilitated by experienced ECMO nurses, nurse educators or perfusionists, with additional support staff. Faculty approached participants' learning cognisant of Dewey's (1938) theory of experience [23], whereby we sought to provide participants with an educative experience conducive to clinical, intellectual and collaborative growth. Conversely, a miseducative experience had the potential to affect or distort individuals' learning and responsiveness to further experiences [24]. An observer-participant model, informed by Kolb's Experiential Learning Theory [25], required participants to actively observe, listen and reflect on others' experiences. Research suggests that simulation-based healthcare education can improve knowledge retention, clinical reasoning and skill transfer by engaging learners in experiential learning processes involving concrete experience, reflective observation, abstract conceptualisation and active experimentation [25]. This approach promoted collective experiential learning through exposure to both optimal practice and error.

For the hands-on component of the workshop, participants were divided into two small groups of seven (reflecting a typical

cohort of 14 participants), comprising an equal mix of clinician groups. Each small group was allocated to an ECMO training circuit to handle components, trace circuit flow and observe key elements such as pumps and oxygenators. Troubleshooting scenarios (e.g., volume insufficiency, circuit kicking, air removal and hand-cranking) and safety checks were demonstrated by faculty and practised by each participant. ECMO circuits were also made available during break periods to support the consolidation of individual participants' learning.

A dedicated 45-min *Cannulation Issues* session complemented circuit training. Led by an ICU medical specialist, cardiothoracic surgeon or cardiothoracic anaesthetist, with support from ECMO-experienced nurses and/or perfusionists, this simulation used a cannulation mannequin and primed ECMO circuit within a mock clinical environment. Participants engaged in a *talk and cannulate* approach during simulated urgent VA-ECMO cannulation, undertaking tasks such as vessel identification, dilation and circuit connection. Most participants were directly involved, with role allocation typically prioritising medical officers for vascular access and registered nurses for circuit management.

High-fidelity [highly realistic] simulation further consolidated explicit and tacit knowledge through two extended (>1 h) interdisciplinary scenarios involving ECMO emergencies (e.g., hypoxaemia on VV-ECMO, severe access insufficiency, pump failure), followed by structured debriefing. Faculty included ECMO nurses, nurse educators, ICU medical specialists and perfusionists, supporting scenario facilitation, simulation control and circuit manipulation. Simulations were conducted in a realistic clinical environment with all participants present and adhered to the observer participant model, whereby individuals could assist only when directed by the designated team leader. Scenarios typically progressed from bedside nurse to nursing team leader and subsequently to ICU registrar or senior clinician.

Fidelity in simulation is a multidimensional construct reflecting the degree of realism and exactness achieved through the design of equipment, environment and scenario as well as the overall believability of the experience [26] It encompasses physical, psychological and conceptual dimensions and is commonly described along a continuum from low to high fidelity [27] Our simulation workshops were considered high fidelity through alignment with intended learning outcomes and supported with realistic interdisciplinary scenarios. These scenarios employed artefacts such as echocardiogram videos, arterial blood gases, chest X-rays and flowing ECMO circuits designed to enable faculty to remotely initiate emergency scenarios such as air embolism and suck down events.

Debriefing focused on clinical decision-making and both technical and non-technical skills, including communication, leadership and situational awareness. Emphasis was placed on examining differences between ECMO-specific management and standard ICU practice and on exploring interdisciplinary mental models in the management of ECMO emergencies. All attendees were considered active participants in both simulation and debriefing, regardless of their direct involvement in scenario enactment.

3.6 | Data Collection

Participants completed the Likert-type, self-administered, paper evaluation survey (see [File S2](#)) immediately prior to and following the workshop. To facilitate the matching of individual pre- and post-survey responses, participants could elect to provide their own name or use a pseudonym. Data from the matched forms were de-identified when it was entered into Excel spreadsheets on a password-protected computer.

The survey focused on three discrete constructs of knowledge, confidence and skills, to avoid the use of complex or mixed constructs contained in some instruments. By limiting construct complexity and using a Likert-type format, the survey design aimed to minimise cognitive load and respondent fatigue, thereby improving the reliability of self-ratings and the validity of observed pre- to post-workshop changes [28, 29] A dichotomous item assessed participants' perceived ability to apply acquired knowledge to clinical practice (yes/no). Additionally, free-text responses were collected to capture participants' perspectives on workshop strengths and areas for improvement. Thus, the survey instrument was designed to be efficient and straightforward to complete, to encourage reflection on learning progress and to capture participants' perceived level of understanding, confidence and skill from the beginning to the conclusion of the workshop.

Our bespoke education evaluation survey was peer reviewed for clarity and face validity by a convenience sample of ICU clinicians [30]. All items used 9-point Likert-type scales, where 1 represented the lowest and 9 the highest level of each attribute. The use of a 9-point Likert-type scale for the pre- and post-workshop survey was informed by a self-assessment instrument from an earlier ECMO educational evaluation [13]. Likert-type scales have been used to quantify perceived knowledge, confidence and skills [28, 31] in educational evaluations [32]. Scales with 7–10 response options improve sensitivity without compromising reliability [33]. The 9-point scale used in this study was anchored from low to high, as ascending response options may reduce response error and improve survey usability [34]. The numeric range allowed participants to express gradations in perceived change while maintaining a single, easily interpretable continuum for analysis [29].

3.7 | Outcomes Measures

The primary outcomes were self-reported perceptions of the following:

1. Knowledge of VV-ECMO
2. Knowledge of VA-ECMO.
3. Confidence in managing ECMO in the ICU.
4. Confidence in managing ECMO emergencies.
5. Skills in managing the ECMO circuit.

Secondary outcomes were self-reported perceptions of the following:

1. Intention to apply acquired knowledge to clinical practice.

TABLE 1 | ECMO pre- and post-workshop scores by domain.

Outcomes	<i>n</i>	Pre-test mean (SD)	Post-test mean (SD)	Mean change	95% CI	<i>p</i>
Knowledge: VV-ECMO	275	3.63 (1.72)	6.59 (1.19)	+2.95	2.78–3.12	<0.001
Knowledge: VA-ECMO	275	3.44 (1.72)	6.41 (1.26)	+2.97	2.80–3.14	<0.001
Confidence managing ECMO in ICU	275	3.24 (1.87)	6.31 (1.36)	+3.07	2.88–3.25	<0.001
Confidence managing ECMO emergencies	275	2.42 (1.65)	6.09 (1.42)	+3.68	3.49–3.87	<0.001
Self-rated skill managing ECMO circuit	275	2.41 (1.56)	6.10 (1.42)	+3.69	3.50–3.89	<0.001

Note: All bold *p* values are statistically significant.

2. Workshop strengths and areas for improvement.

3.8 | Data Analysis

Continuous variables were summarised as mean (SD) and range. Pre- and post-workshop scores were compared using paired *t*-tests, with mean change and 95% confidence intervals (CI) calculated for each outcome. The software Stata/BE 17.0 was utilised for all analyses (Revision 21 May 2024 Copyright 1985–2021 StataCorp LLC). A *p*-value of <0.05 was considered statistically significant. We compared the change in pre–post workshop scores for each outcome across the clinician groups using one-way ANOVA with Bonferroni-adjusted pairwise comparisons. Descriptive summaries were generated for baseline proficiency levels informed by Benner's Stages of Clinical Competence [35] and the proportion of participants indicating they would apply their learning in practice. Two faculty members independently reviewed and re-reviewed participant responses to achieve data familiarisation. Free-text feedback was then analysed thematically, with responses grouped into descriptive themes through the exploration, identification, arrangement, interpretation and presentation of patterns within the data [36].

4 | Results

Matched pre- and post-workshop survey data were collected and analysed for 275 participants across 20 workshops, representing a 99% response rate.

Demographic data were not formally collected. Informal introductions during *Getting to Know You* sessions indicated that the registered nurse cohort comprised predominantly ICU nurses attending for ECMO credentialling, many with limited ICU experience (approximately 1–2years) and, in some cases, undertaking ICU post-graduate education. The nurse cohort showed a range of experience levels, including nurse educators, team and shift leaders and advanced practice nurses, some with substantial ECMO expertise. The medical officer cohort consisted primarily of ICU registrars participating as part of their clinical rotations, alongside ICU specialists, medical directors and a Professor of Intensive Care Medicine. Physiotherapists and

perfusionists were few in number and represented a range of experience levels, generally tending towards early-career practitioners in ICU or in their current roles, though this was not universal. Although attendance was voluntary and linked to ECMO credentialing pathways, some participants reported that their attendance was mandated or highly encouraged by their employing institution.

At baseline, participants self-classified their overall ECMO proficiency using a four-level scale from lowest (level 1) to highest (level 4). Most participants (*n*=178; 65%) were at the lowest proficiency level, while only six (2%) selected the highest level, indicating that the cohort was predominantly ECMO novices. Clinicians were predominantly registered nurses (*n*=184; 67%) and medical officers (*n*=85; 31%), with smaller numbers of perfusionists (*n*=3; 1%) and physiotherapists (*n*=3; 1%).

4.1 | Changes in Self-Reported Knowledge, Confidence and Skills

There were significant mean improvements across all domains. There were significant improvements in confidence in managing ECMO emergencies and self-rated circuit skills. Collective pre- and post-workshop results are presented in Table 1. Results were stratified by clinician group and are presented in Tables 2–4.

4.2 | Domain-Specific Changes in Knowledge, Confidence and Skills by Clinician Group

When analysed by domain and clinician type (Tables 2–4), improvements were observed across all outcome measures, with consistent variation in magnitude between clinician groups. The Bonferroni-adjusted pairwise comparisons are provided (Table 5). In analyses of change scores, registered nurses demonstrated significantly greater improvement in confidence managing ECMO in the ICU than medical officers (mean difference +1.0; adjusted *p*<0.001) and perfusionists (mean difference +2.4; adjusted *p*=0.037). Nurses also demonstrated significantly greater improvements than medical officers in self-reported VV-ECMO knowledge, VA-ECMO knowledge, confidence managing ECMO emergencies and self-rated ECMO circuit management skill. No

TABLE 2 | VV- and VA-ECMO knowledge change scores by clinician group.

Clinician group	n	Mean change	SD	95% CI	p
VV-ECMO knowledge					
Registered nurses	184	+3.3	1.4	3.1–3.5	<0.001
Medical officers	85	+2.2	1.3	1.9–2.5	<0.001
Perfusionists	3	+1.7	0.6	0.2–3.1	0.037
Physiotherapists	3	+2.7	0.6	1.2–4.1	0.015
Overall	275	+2.95	1.4	2.8–3.1	<0.001
VA-ECMO knowledge					
Registered nurses	184	+3.3	1.4	3.1–3.5	<0.001
Medical officers	85	+2.3	1.2	2.1–2.6	<0.001
Perfusionists	3	+1.7	0.6	0.2–3.1	0.037
Physiotherapists	3	+3.0	1.0	0.5–5.5	0.035
Overall	275	+2.97	1.4	2.8–3.1	<0.001

Note: All bold *p* values are statistically significant.

other between-group comparisons reached statistical significance after adjustment for multiple comparisons.

The clinician group comparisons demonstrated that nurses showed the greatest improvements in most domains, compared to medical officers, perfusionists and physiotherapists. Nurses showed significantly greater improvements in self-reported VV-ECMO and VA-ECMO knowledge scores compared to medical officers (mean differences +1.2 and +0.9, respectively; both adjusted $p < 0.001$), confidence in managing ECMO emergencies (mean difference: +0.9; $p < 0.001$) and self-rated skill managing the ECMO circuit (mean difference: +0.8; adjusted $p < 0.001$).

4.3 | Knowledge (VV- and VA-ECMO)

All clinician groups demonstrated increased self-reported knowledge of both VV- and VA-ECMO following the workshop. Registered nurses showed the greatest mean improvement in both domains (mean change +3.3 for VV- and VA-ECMO), followed by physiotherapists (VV: +2.7; VA: +3.0) and medical officers (VV: +2.2; VA: +2.3). Perfusionists demonstrated the smallest gains (+1.7 for both domains). Confidence intervals for registered nurses were narrow (3.1–3.5) and showed minimal overlap with those of medical officers, suggesting a meaningful difference between these groups. In contrast, estimates for perfusionists and physiotherapists were less precise due to very small sample sizes.

TABLE 3 | VV- and VA-ECMO confidence change scores by clinician group.

Clinician group	n	Mean change	SD	95% CI	p
VV- and VA-ECMO confidence in routine ECMO management in ICU					
Registered nurses	184	+3.4	1.6	3.2–3.6	<0.001
Medical Officers	85	+2.4	1.3	2.1–2.7	<0.001
Perfusionists	3	+1.0	1.0	–1.5–3.5	0.225
Physiotherapists	3	+3.0	2.6	–3.5–9.6	0.188
Overall	275	+3.07	1.6	2.9–3.2	<0.001
VV- and VA-ECMO confidence in managing ECMO emergencies					
Registered nurses	184	+4.0	1.6	3.8–4.2	<0.001
Medical officers	85	+3.1	1.4	2.8–3.3	<0.001
Perfusionists	3	+2.0	0.0	—	—
Physiotherapists	3	+3.7	1.5	–0.1–7.5	0.05
Overall	275	+3.7	1.5	3.5–3.9	<0.001

Note: All bold *p* values are statistically significant.

TABLE 4 | VV- and VA-ECMO self-rated circuit skill change scores by clinician group.

VV- and VA-ECMO self-rated skill managing the ECMO circuit					
Clinician group	n	Mean change	SD	95% CI	p
Registered nurses	184	+3.9	1.5	3.7–4.2	<0.001
Medical officers	85	+3.1	1.5	2.8–3.4	<0.001
Perfusionists	3	+1.7	0.6	0.2–3.1	0.037
Physiotherapists	3	+4.0	1.7	–0.3–8.3	0.057
Overall	275	+3.69	1.6	3.5–3.9	<0.001

Note: All bold *p* values are statistically significant.

4.4 | Confidence (Routine ECMO Management and Emergencies)

Improvements in confidence were observed across all clinician groups, with greater gains seen in managing ECMO emergencies compared with routine ICU ECMO care. For confidence in routine ECMO management, registered nurses demonstrated the largest increase (mean change +3.4), compared with medical officers (+2.4). Perfusionists showed minimal change (+1.0), while physiotherapists demonstrated moderate gains (+3.0), although with wide confidence intervals indicating uncertainty.

For confidence in managing ECMO emergencies, larger improvements were observed overall. Registered nurses (+4.0) and

TABLE 5 | Bonferroni-adjusted pairwise comparisons of clinician groups.

Comparison	Mean difference (change)	Adjusted <i>p</i>
Knowledge—VV-ECMO		
Nurses vs. medical officers	+1.2	<0.001
Nurses vs. perfusionists	+1.6	0.20
Nurses vs. physiotherapists	+0.7	1.00
Medical officers vs. perfusionists	+0.5	1.00
Medical officers vs. physiotherapists	+0.4	1.00
Perfusionists vs. physiotherapists	−1.0	1.00
Knowledge—VA-ECMO		
Nurses vs. medical officers	+0.9	<0.001
Nurses vs. perfusionists	+1.6	0.20
Nurses vs. physiotherapists	+0.3	1.00
Medical officers vs. perfusionists	+0.7	1.00
Medical officers vs. physiotherapists	+0.7	1.00
Perfusionists vs. physiotherapists	−1.3	1.00
Confidence managing ECMO in ICU		
Nurses vs. medical officers	+1.0	<0.001
Nurses vs. perfusionists	+2.4	0.037
Nurses vs. physiotherapists	+0.4	1.00
Medical officers vs. perfusionists	+1.4	0.7
Medical officers vs. physiotherapists	+0.6	1.00
Perfusionists vs. physiotherapists	−2.0	0.6
Confidence managing ECMO emergencies		
Nurses vs. medical officers	+0.9	<0.001
Nurses vs. perfusionists	+2.0	0.13

(Continues)

TABLE 5 | (Continued)

Comparison	Mean difference (change)	Adjusted <i>p</i>
Nurses vs. physiotherapists	+0.3	1.0
Medical officers vs. perfusionists	+1.0	1.0
Medical officers vs. physiotherapists	+0.6	1.0
Perfusionists vs. physiotherapists	−1.7	1.0
Self-rated skill managing the ECMO circuit		
Nurses vs. medical officers	+0.8	<0.001
Nurses vs. perfusionists	+2.3	0.05
Nurses vs. physiotherapists	0.0	1.0
Medical officers vs. perfusionists	+1.4	0.6
Medical officers vs. physiotherapists	−0.9	1.0
Perfusionists vs. physiotherapists	−2.3	0.3

Note: Values are mean differences with Bonferroni-adjusted *p*-values. Statistically significant results are shown in bold.

physiotherapists showed the greatest increase (+3.7) followed by medical officers (+3.1). Estimates for physiotherapists and perfusionists were limited by a small sample size, with imprecise or non-estimable confidence intervals.

4.5 | Self-Rated ECMO Circuit Management Skills

Substantial improvements in self-rated ECMO circuit management skills were observed across all groups. Physiotherapists (+4.0) and registered nurses (+3.9) demonstrated the largest mean change, followed by medical officers (+3.1). Perfusionists showed smaller gains (+1.7). Confidence intervals for registered nurses and medical officers were relatively narrow, whereas those for physiotherapists were wide, reflecting limited precision.

4.6 | Intention to Apply Learning to Practice

The mean score for the binary item capturing whether participants felt they could apply workshop learning to their clinical practice was 0.996 (SD: 0.06), indicating that most participants (99.6%) answered positively. This suggests a high perceived relevance and alignment of the workshop content to ECMO clinical practice.

4.7 | Key Themes From Participant Free Text Feedback

4.7.1 | Value of Hands-On Learning

Participants consistently highlighted the importance of practical, tactile experience with ECMO circuitry. Direct interaction with components such as pumps and oxygenators enhanced understanding and confidence. As one participant noted, 'Hands on practice very helpful. Seeing and touching all the bits and pieces'.

4.7.2 | Effectiveness of Simulation-Based Training

Simulation scenarios were widely regarded as one of the most valuable aspects of the course, particularly for developing skills in emergency management, teamwork and communication. Feedback emphasised their realism and relevance, with one participant stating, 'Thanks for the great course...the cannulation session was outstanding, and the team-based circuit problem solving. Day was extremely good'.

4.7.3 | Strength of Interdisciplinary Faculty

The faculty were frequently described as knowledgeable, supportive and engaging. Participants appreciated their approachable teaching style and ability to simplify complex concepts. Representative comments included 'Wonderful team. Big thanks' and 'Very thorough and enthusiastic staff'.

4.7.4 | Positive Overall Workshop Experience

Attendees consistently described the workshop as practical, informative and engaging. The structure and delivery were well received, with participants noting, 'The day was simple and well structured. Thanks!' and 'This was brilliant...you were all very patient with my minimal knowledge/confidence'. Faculty were particularly praised for making complex material understandable.

4.7.5 | Seeking More Hands-On Practice

While feedback was overwhelmingly positive, some participants expressed a desire for more time to consolidate their skills and greater exposure to less common scenarios. As one participant reflected, 'Really valuable hands on practice. I need more to feel confident'.

5 | Discussion

In this multi-course evaluation of a single-day, ECMO simulation workshop, we observed significant improvements in clinicians' perceived ECMO knowledge, confidence and skill across all domains. Baseline data showed that most participants identified as ECMO novices; after the workshop,

average scores increased by approximately 3 points on a 9-point scale for knowledge of VV- and VA-ECMO, confidence in routine ICU management and emergencies and self-rated circuit skills.

The exceptionally high response rate can be attributed to the evaluation being administered to a captive and highly engaged participant group, with respondents given the option to remain anonymous. The evaluation was simple, brief and easy to complete, and participants were provided with a clear explanation of its purpose and importance. In addition, participants were familiar with completing education evaluations, which likely supported their willingness to participate. Although the high response rate helped minimise the risk of non-response bias, response bias may still have occurred, with participants potentially providing more favourable responses due to social desirability or the evaluation context [37]. Anonymous responses were intended to minimise this risk and encourage honest feedback.

Overall, the workshop was associated with broad improvements across all domains of knowledge, confidence and skills. Across the interdisciplinary cohort, improvements in confidence during ECMO emergencies and in technical circuit management skills were among the most pronounced. Overall, after adjustment for multiple comparisons, nurses exhibited the greatest improvements across ECMO knowledge and confidence scores, particularly compared with medical officers. Medical officers showed smaller but consistent gains. These differences may reflect variations in professional training, clinical responsibilities and exposure to routine ICU ECMO management between nursing and medical staff [38]; however, these factors were not measured sufficiently to explain between-group differences. Estimates for perfusionists and physiotherapists should be considered cautiously, given the limited sample sizes and broad confidence intervals.

Although subgroup analysis indicated that nursing participants exhibited an approximately one-point greater increase in Likert scale scores compared with medical officers, this finding should not be interpreted as evidence of greater learning. Likert scale data capture perceived, self-reported changes rather than objective measures of knowledge or skill acquisition. As such, the observed differences reflect greater perceived improvement rather than a definitive difference in actual learning between professional groups.

More broadly, inter-group comparisons should be interpreted cautiously in the context of an interprofessional workshop grounded in collaborative learning principles. Despite nurses' perceptions of greater learning gains, disaggregating results by discipline risks undermining the philosophical foundations of interdisciplinary education and may limit the ability to draw meaningful conclusions. In this study, the use of pooled, interdisciplinary data represent a methodologically coherent approach for analysing subjective outcomes within an interdisciplinary cohort. Future studies employing similar interprofessional frameworks and subjective evaluation measures should therefore consider prioritising pooled analyses to preserve the integrity of the educational model.

Almost all participants indicated that they felt able to apply what they had learned to their clinical practice. These results indicate that a thoughtfully structured, single-day ECMO simulation workshop can significantly enhance clinicians' confidence in managing ECMO patients, particularly when conducted using an interdisciplinary approach. Our findings align with emerging international ECMO education literature [14, 39]. Single-day ECMO task trainer-based courses in the USA have demonstrated high rates of successful skill demonstration and improved knowledge and confidence, comparable to longer, live-tissue training programs [18]. A prospective cohort study based in one hospital in the United States reported that a structured ECMO curriculum for critical care nurses, incorporating didactic content, simulation and written assessment, produced significant improvements in examination scores among 301 ECMO-naïve nurses, with median score gains of 23 percentage points in the basic course and 8.4 points in an advanced course [17]. A prospective cohort study of rapid interdisciplinary ECMO training for a large health facility in the United States reported a 20-point median gain in examination scores (70%–90%) and high perceived usefulness of the course [14]. Our results extend this evidence by demonstrating that similar benefits can be achieved in an adult ECMO programme using a single-day interdisciplinary simulation workshop model [13, 28]. Despite the workshop's single-day format, the consistent direction of improvements mirrors those outcomes reported in previous ECMO educational studies using simulation-based curricula and rapid interdisciplinary training programmes [13, 14, 17, 18].

The broader simulation literature in critical care supports the use of simulation for high-risk, low-frequency events, inter-professional teamwork [40, 41] and systems testing [16]. Our findings that confidence in managing ECMO emergencies and self-rated circuit skills improved most strongly are consistent with this emphasis on simulation as a tool for experiential learning in complex scenarios [42].

A Delphi consensus on essential adult ECMO skills has emphasised the importance of clearly defining the knowledge base, technical competencies and professional attitudes required for effective extracorporeal membrane oxygenation (ECMO) practice [15]. Although the ECMO simulation workshop described here was established in 2010, approximately 12 years prior to the publication of this consensus, its educational focus on core circuit knowledge, emergency troubleshooting and team communication demonstrates strong alignment with these identified domains. This alignment suggests that the workshop could be further strengthened through formal mapping to the consensus framework.

At the time of its inception, the educational strategies underpinning the workshop reflected emerging approaches to simulation-based learning. These methods are now generally regarded as best practice in healthcare and, more specifically, ECMO education [43]. Notably, while the existing literature frequently describes ECMO education programmes tailored to specific professional groups, such as nurses or medical officers, contemporary educational theory supports interprofessional education as the preferred model [44]. Interprofessional learning fosters shared understanding, enhances communication, promotes collaborative practice and improves patient outcomes [45]

all of which are critical in the high-risk, team-based context of ECMO delivery.

The dissemination of this ECMO workshop programme has extended beyond the originating healthcare organisation, with course content and educational approaches shared across multiple centres within Australia and internationally. As a result, several institutions have developed and implemented their own ECMO education programmes, reflecting both the model's transferability and its relevance across diverse clinical settings.

5.1 | Implications for ECMO Education and Service Delivery

From a practical perspective, these findings support both the feasibility and utility of incorporating a single-day ECMO simulation workshop into ECMO service development and maintenance strategies. Several key implications emerge.

First, the scalability of a single-day format represents a significant advantage. Such a design is relatively straightforward to schedule and replicate, enabling progressive training of large numbers of clinicians over time. In our ECMO simulation programme, 35 courses were delivered to over 494 participants while maintaining manageable resource requirements.

Second, the interdisciplinary nature of the workshop is a critical strength. The inclusion of registered nurses, medical officers, perfusionists and physiotherapists within shared simulation scenarios reflects routine intensive care practice and promotes the development of shared mental models, effective communication and role clarity [16].

Third, the observed improvements in self-reported preparedness suggest that the workshop may provide a valuable foundation for local ECMO credentialing pathways. This foundational training can be supplemented by supervised clinical exposure and ongoing continuing education, alongside longitudinal data to support competency development over time.

Finally, alignment with established consensus frameworks may further enhance curriculum design. The adult essential ECMO skills framework provides a structured approach to defining key knowledge domains, technical competencies and professional attitudes and could be used to map and refine the existing workshop curriculum [15].

5.2 | Strengths and Limitations

There are several strengths of this study. First, a large sample ($n = 275$) of predominantly ECMO-naïve or early-career clinicians with complete paired data measuring multiple outcome domains (knowledge, confidence and skills) and supportive qualitative feedback data. Second, our consistent, real-world education program has been implemented over many years in a high-volume ECMO centre. Third, subsequent publications examining interdisciplinary simulation-based ECMO education have identified core design features that closely align with the components embedded within our workshop. Notably, many of

these elements were incorporated into the programme before their formal recognition as best practice, indicating that our workshop curriculum anticipated later consensus recommendations [43].

Several limitations are acknowledged. First, all primary outcomes were self-reported, which may overestimate learning and competence and introduce response bias. Second, evaluations were completed immediately after the workshop, capturing short-term learning only. Longer-term retention of knowledge, confidence or skills was not captured and was beyond the scope of the study. Third, the pre-post single-group design cannot control for secular trends, prior ECMO exposure, multiple workshop attendance, or other learning activities. Fourth, participant demographic data were limited to clinician profession and self-rated proficiency, limiting subgroup analyses such as ICU experience. Finally, this single-centre design reflects the context of a single adult quaternary centre and may not generalise to settings with a different case-mix, resources or baseline ECMO expertise. Despite these limitations, the magnitude and consistency of the observed improvements across multiple domains and clinician groups, together with supporting qualitative feedback, provide strong evidence that the workshop was perceived by participants as educationally effective.

6 | Implications for Practice

These findings support the integration of structured, simulation-based ECMO education into ECMO service development, clinician credentialing and ongoing continuing professional development. Future research should evaluate long-term retention, translation of learning into clinical behaviour and the potential impact of such programmes on ECMO processes and patient outcomes.

7 | Conclusion

A single-day interdisciplinary ECMO simulation workshop delivered through an adult quaternary hospital simulation centre was associated with large, immediate improvements in ICU clinicians' self-reported ECMO knowledge, confidence and circuit management skills. The program predominantly served clinicians with limited prior ECMO experience and was rated as highly relevant to clinical practice, with almost all participants expecting to apply their learning at the bedside.

Author Contributions

Susan Whittam: project administration, methodology, resources, writing – original draft; writing – review and editing. **Jeff Breeding:** project administration, formal analysis, conceptualisation, methodology, resources, writing – original draft, writing – review and editing. **Belinda Causby:** methodology, writing – review and editing. **Nerilee Torning:** resources, methodology, writing – review and editing. **Sarah Birch:** writing – review and editing. **Hergen Buscher:** conceptualisation, resources, writing – review and editing. **Carmen Frost:** resources, writing – review and editing. **Keith Adkins:** resources, writing – review

and editing. **David Lowe:** conceptualisation, resources, writing – review and editing. **Roger Pye:** conceptualisation, resources, writing – review and editing. **Adam Roshan:** resources, writing – review and editing. **George Ntoumenopoulos:** formal analysis, validation, methodology, writing – original draft, writing – review and editing.

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Ethics Statement

The study used retrospective, de-identified educational quality-improvement data. St Vincent's Hospital Sydney Human Research Ethics Committee (HREC) confirmed that as the study aligned with the NSW Health Quality Improvement guidelines, formal HREC approval was not required. Completion of pre- and post-workshop evaluation surveys implied consent to the quality improvement process.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. B. Patel, S. Chatterjee, S. Davignon, and J. P. Herlihy, "Extracorporeal Membrane Oxygenation as Rescue Therapy for Severe Hypoxemic Respiratory Failure," *Journal of Thoracic Disease* 11, no. Suppl 14 (2019): S1688–S1697, <https://doi.org/10.21037/jtd.2019.05.73>.
2. D. M. Castro, I. Morris, R. Teijeiro-Paradis, and E. Fan, "Monitoring During Extracorporeal Membrane Oxygenation," *Current Opinion in Critical Care* 28, no. 3 (2022): 348–359, <https://doi.org/10.1097/MCC.0000000000000939>.
3. A. Davies, D. Jones, M. Bailey, et al., "Extracorporeal Membrane Oxygenation for 2009 Influenza A(H1N1) Acute Respiratory Distress Syndrome," *Journal of the American Medical Association* 302, no. 17 (2009): 1888–1895, <https://doi.org/10.1001/jama.2009.1535>.
4. C. Jones, C. Hommers, B. Burns, and P. Forrest, "ECMO Retrieval in NSW and Beyond," *Current Anaesthesia and Critical Care* 21, no. 5–6 (2010): 282–286, <https://doi.org/10.1016/j.cacc.2010.07.004>.
5. P. Forrest, J. Ratchford, B. Burns, et al., "Retrieval of Critically Ill Adults Using Extracorporeal Membrane Oxygenation: An Australian Experience," *Intensive Care Medicine* 37, no. 5 (2011): 824–830, <https://doi.org/10.1007/s00134-011-2158-8>.
6. S. C. Duffin, J. H. Askew, T. J. Southwood, P. Forrest, B. Plunkett, and R. J. Totaro, "An Intensivist-Led ECMO Accreditation Pathway and

- Safety Data Over the First 4 Years,” *Critical Care and Resuscitation* 26, no. 1 (2024): 41–46, <https://doi.org/10.1016/j.ccrj.2023.11.006>.
7. NSW Health Emergency Management Committee, *Key Recommendations on Pandemic (H1N1) 2009 Influenza* (NSW Department of Health, 2010), <https://www.health.nsw.gov.au/pandemic/Documents/key-recommendations-pandemic-H1N1-NSW-health-2010.pdf>.
8. NSW Agency for Clinical Innovation, *ECMO (Extracorporeal Membrane Oxygenation) Services - Adult Patients: Organisational Model of Care* (Agency for Clinical Innovation, 2020), https://aci.health.nsw.gov.au/__data/assets/pdf_file/0004/624280/ACI-ICNSW-ECMO-adult-patients-model-of-care.pdf.
9. G. MacLaren, D. Brodie, R. Lorusso, G. Peek, R. Thiagarajan, and L. Vercaemst, *Extracorporeal Life Support: The ELSO Red Book*, 6th ed. (Extracorporeal Life Support Organization, 2022).
10. M. Puslecki, M. Dabrowski, M. Ligowski, et al., “Comprehensive Assessment of a Nationwide Simulation-Based Course for Artificial Life Support,” *PLoS One* 16, no. 10 (2021): e0257162, <https://doi.org/10.1371/journal.pone.0257162>.
11. M. F. Weems, P. S. Friedlich, L. P. Nelson, et al., “The Role of Extracorporeal Membrane Oxygenation Simulation Training at Extracorporeal Life Support Organization Centers in the United States,” *Simulation in Healthcare* 12, no. 4 (2017): 233–239, <https://doi.org/10.1097/SIH.0000000000000243>.
12. B. Zakhary, K. Shekar, R. Diaz, et al., “Position Paper on Global ECMO Education and Educational Agenda for the Future: A Statement From the Extracorporeal Life Support Organization ECMOed Taskforce,” *Critical Care Medicine* 48, no. 3 (2020): 406–414, <https://doi.org/10.1097/CCM.0000000000004158>.
13. V. Fouilloux, C. Gran, C. Guervilly, J. Breaud, F. El Louali, and P. Rostini, “Impact of Education and Training Course for ECMO Patients Based on High-Fidelity Simulation: A Pilot Study Dedicated to ICU Nurses,” *Perfusion* 34, no. 1 (2019): 29–34, <https://doi.org/10.1177/0267659118789824>.
14. W. D. Gannon, Y. Tipograf, J. W. Stokes, et al., “Rapid Training in Extracorporeal Membrane Oxygenation for a Large Health System,” *American Thoracic Society Scholar* 1, no. 4 (2020): 406–415, <https://doi.org/10.34197/ats-scholar.2020-0028IN>.
15. H. Peperstraete, A. Steenhout, F. De Somer, P. Depuydt, E. Hoste, and I. Van Herzele, “Adult Essential Extracorporeal Membrane Oxygenation (ECMO) Skills for Use in an e-Learning Program for ICU Physicians, Nurses and Perfusionists: A Consensus by a Modified Delphi Questionnaire,” *BMC Medical Education* 22, no. 1 (2022): 786, <https://doi.org/10.1186/s12909-022-03764-2>.
16. N. Seam, A. J. Lee, M. Vennero, and L. Emlet, “Simulation Training in the ICU,” *Chest* 156, no. 6 (2019): 1223–1233, <https://doi.org/10.1016/j.chest.2019.07.011>.
17. W. D. Gannon, L. Craig, L. Netzel, et al., “Curriculum to Introduce Critical Care Nurses to Extracorporeal Membrane Oxygenation,” *American Journal of Critical Care* 29, no. 4 (2020): 262–269, <https://doi.org/10.4037/ajcc2020739>.
18. J. K. Maddry, R. M. Paredes, T. Abdurashidov, et al., “Efficacy of a Single-Day Task Trainer-Based Extracorporeal Membrane Oxygenation Training Course,” *AEM Education and Training* 6, no. 6 (2022): e10806, <https://doi.org/10.1002/aet2.10806>.
19. M. N. Lutfiyya, L. F. Chang, C. McGrath, C. Dana, and M. S. Lipsky, “The State of the Science of Interprofessional Collaborative Practice: A Scoping Review of the Patient Health-Related Outcomes-Based Literature Published Between 2010 and 2018,” *PLoS One* 14, no. 6 (2019): e0218578, <https://doi.org/10.1371/journal.pone.0218578>.
20. C. J. Joyce, D. A. Cook, J. Walsham, et al., “Low Volume ECMO Results Study,” *Critical Care and Resuscitation* 22, no. 4 (2020): 327–334, <https://doi.org/10.51893/2020.4.OA5>.
21. A. Sharma, N. T. Minh Duc, T. Luu Lam Thang, et al., “A Consensus-Based Checklist for Reporting of Survey Studies (CROSS),” *Journal of General Internal Medicine* 36, no. 10 (2021): 3179–3187, <https://doi.org/10.1007/s11606-021-06737-1>.
22. P. I. Watts, D. S. McDermott, G. Alinier, et al., “Healthcare Simulation Standards of Best Practice: Simulation Design,” *Clinical Simulation in Nursing* 58 (2021): 14–21, <https://doi.org/10.1016/j.ecns.2021.08.009>.
23. J. Dewey, *Experience and Education* (Macmillan, 1938).
24. S. Whittam, N. Tarning, and J. Patching, “A Narrative Inquiry Approach to Understanding Senior Intensive Care Nurses’ Experiences of Working With New Graduate Nurses,” *Journal of Clinical Nursing* 30, no. 21–22 (2021): 3314–3329, <https://doi.org/10.1111/jocn.15844>.
25. M. Wijnen-Meijer, T. Brandhuber, A. Schneider, and P. O. Berberat, “Implementing Kolb’s Experiential Learning Cycle by Linking Real Experience, Case-Based Discussion and Simulation,” *Journal of Medical Education and Curricular Development* 9 (2022): 23821205221091511, <https://doi.org/10.1177/23821205221091511>.
26. Y. F. Choi and T. W. Wong, “High-Fidelity Simulation Training Programme for Final-Year Medical Students: Implications From the Perceived Learning Outcomes,” *Hong Kong Medical Journal* 25, no. 5 (2019): 392–398, <https://doi.org/10.12809/hkmj197898>.
27. P. Rashid and T. R. J. Gianduzzo, “Urology Technical and Non-Technical Skills Development: The Emerging Role of Simulation,” *BJU International* 117, no. Suppl 4 (2016): 9–16, <https://doi.org/10.1111/bju.13259>.
28. A. S. Said, E. Cooley, E. A. Moore, et al., “Development of a Standardized Assessment of Simulation-Based Extracorporeal Membrane Oxygenation Educational Courses,” *American Thoracic Society Scholar* 3, no. 2 (2022): 242–257, <https://doi.org/10.34197/ats-scholar.2021-0068OC>.
29. J. Rattray and M. C. Jones, “Essential Elements of questionnaire design and development,” *Journal of Clinical Nursing* 16, no. 2 (2007): 234–243, <https://doi.org/10.1111/j.1365-2702.2006.01573.x>.
30. J. M. Latour and L. N. Tume, “How to Do and Report Survey Studies Robustly: A Helpful Mnemonic SURVEY,” *Nursing in Critical Care* 26, no. 5 (2021): 313–314, <https://doi.org/10.1111/nicc.12669>.
31. S. Laschinger, J. Medves, C. Pulling, et al., “Effectiveness of Simulation on Health Profession Students’ Knowledge, Skills, Confidence and Satisfaction,” *International Journal of Evidence-Based Healthcare* 6, no. 3 (2008): 278–302, <https://doi.org/10.1111/j.1744-1609.2008.00108.x>.
32. A. Ahadi, M. Bower, A. Singh, and M. Garrett, “Online Professional Learning in Response to COVID-19: Towards Robust Evaluation,” *Future Internet* 13, no. 3 (2021): 56, <https://doi.org/10.3390/fi13030056>.
33. C. C. Preston and A. M. Colman, “Optimal Number of Response Categories in Rating Scales: Reliability, Validity, Discriminating Power, and Respondent Preferences,” *Acta Psychologica* 104, no. 1 (2000): 1–15, [https://doi.org/10.1016/S0001-6918\(99\)00050-5](https://doi.org/10.1016/S0001-6918(99)00050-5).
34. S. Y. Chyung, M. Kennedy, and I. Campbell, “Evidence-Based Survey Design: The Use of Ascending or Descending Order of Likert-Type Response Options,” *Performance Improvement* 57, no. 9 (2018): 9–16, <https://doi.org/10.1002/pfi.21800>.
35. P. Benner, P. Hooper-Kyriakidis, and D. Stannard, *Clinical Wisdom and Interventions in Acute and Critical Care: A Thinking-In-Action Approach*, 2nd ed. (Springer, 2011).
36. L. S. Nowell, J. M. Norris, D. E. White, and N. J. Moules, “Thematic Analysis: Striving to Meet the Trustworthiness Criteria,” *International Journal of Qualitative Methods* 16, no. 1 (2017): 1609406917733847, <https://doi.org/10.1177/1609406917733847>.
37. A. Althubaiti, “Information Bias in Health Research: Definition, Pitfalls, and Adjustment Methods,” *Journal of Multidisciplinary Healthcare* 9 (2016): 211–217, <https://doi.org/10.2147/JMDH.S104807>.

38. P. Ross, J. Sheldrake, D. Ilic, et al., "An Exploration of Intensive Care Nurses' Perceptions of Workload in Providing Extracorporeal Membrane Oxygenation (ECMO) Support: A Descriptive Qualitative Study," *Australian Critical Care* 37, no. 4 (2024): 585–591, <https://doi.org/10.1016/j.aucc.2023.12.002>.
39. R. Brum, R. Rajani, E. Gelandt, et al., "Simulation Training for Extracorporeal Membrane Oxygenation," *Annals of Cardiac Anaesthesia* 18, no. 2 (2015): 185–190, <https://doi.org/10.4103/0971-9784.154472>.
40. R. R. Ling, A. Milas, J. K. Wang, et al., "Simulation-Based Education for Extracorporeal Membrane Oxygenation and Strategies for Implementation: A Systematic Scoping Review," *Simulation in Healthcare* 21, no. 1 (2026): 57–74, <https://doi.org/10.1097/SIH.0000000000000884>.
41. P. K. Han, N. J. Purkey, K. W. Kuo, et al., "A Scoping Review and Appraisal of Extracorporeal Membrane Oxygenation Education Literature," *American Thoracic Society Scholar* 3, no. 3 (2022): 468–484, <https://doi.org/10.34197/ats-scholar.2022-0058RE>.
42. A. Labib and G. Alinier, "Transport and Retrieval on Extracorporeal Membrane Oxygenation (ECMO): Setup and Activities of an Immersive Transport and Retrieval on ECMO Workshop," *Journal of Cardiothoracic and Vascular Anesthesia* 35, no. 6 (2021): 1603–1610, <https://doi.org/10.1053/j.jvca.2020.11.069>.
43. E. A. Moore, P. Han, K. Shekar, et al., "ELSO 2025 Narrative Guideline on ECMO Training and Continuing Education," *ASAIO Journal* 72, no. 4 (2026): 274–283, <https://doi.org/10.1097/MAT.00000000000002686>.
44. M. Brewer, S. Evans, L. Gum, F. Kent, and M. Anakin, "Interprofessional Education for the Next 50 Years," *Focus on Health Professional Education* 25, no. 1 (2024): 110–118, <https://doi.org/10.11157/fohpe.v25i1.753>.
45. C. S. Webster, T. Coomber, S. Liu, K. Allen, and T. Jowsey, "Interprofessional Learning in Multidisciplinary Healthcare Teams Is Associated With Reduced Patient Mortality: A Quantitative Systematic Review and Meta-Analysis," *Journal of Patient Safety* 20, no. 1 (2024): 57–65, <https://doi.org/10.1097/PTS.0000000000001170>.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supplement: checklist for reporting of survey studies (CROSS). **File S1:** ICU management of the ECMO patient (course outline). **File S2:** Workshop evaluation.