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Consensus Statement

2025 ELSO Consensus Statement for the Provision and Management of Nutrition Therapy in Critically Ill Adult Patients Requiring Extracorporeal Membrane Oxygenation

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International guidelines for the nutrition management of critically ill adults do not sufficiently cover the unique challenges and considerations of patients receiving extracorporeal membrane oxygenation (ECMO). The aim of the current guideline is to assess the literature informing nutrition provision and practice for patients receiving ECMO and provide clinicians with consensus-based recommendations to inform clinical practice. A group of international experts was convened by the Extracorporeal Life Support Organization (ELSO) to systematically develop consensus-based recommendations for nutrition therapy. Questions of interest were developed by the authors based on those included in guideline recommendations for general critically ill patients on key clinical areas of nutrition provision and practice during critical illness, but specific to the context of patients receiving ECMO. Following question development, a systematic review of the literature was undertaken, recommendations were developed accordingly, and blind voting was undertaken to determine consensus. Study quality was assessed using the National Institute for Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. A total of 31 publications informed the recommendations with no randomized controlled trials found. Sixteen consensus-based recommendations were formulated for 10 clinical questions, of which 11 reached "strong consensus" (100%) and five "consensus" (87.5%). A total of 26 studies were eligible for quality assessment with 24 (92.3%) rated "fair," 1 (3.8%) rated "good," and 1 (3.8%) rated "poor." There is limited high-level evidence to inform nutrition practice in adult patients receiving ECMO. However, these consensus recommendations have been developed using the available observational data, relevant studies of nutrition in general critically ill patients, and the clinical expertise of those working in high-volume ECMO centers and will help to guide nutrition practices in this patient group. *ASAIO Journal* 2026; 72:99–110

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This publication is intended for educational use to build the knowledge of physicians and other health professionals in assessing the conditions and managing the treatment of patients undergoing extracorporeal life support (ECLS)/ECMO and describe what are believed to be useful and safe practice for ECLS and ECMO. The aim of this article is to help clinicians make informed decisions about their patients. Healthcare professionals must make their own treatment decisions about care on a case-by-case basis, after consultation with their patients, using their clinical judgment, knowledge, and expertise. This content does not take the place of physicians' and other health professionals' judgment in diagnosing and treating patients. This content is not intended to and should not be interpreted as setting a standard of care or being deemed inclusive of all proper methods of care nor exclusive of other methods of care directed at obtaining the same

Several best practice guidelines now exist to guide clinicians in patient assessment and the provision of medical nutrition therapy during critical illness.[1–5] These guidelines consider critically ill patients as a whole population, with small sections dedicated to specific groups (*e.g.,* those receiving renal replacement therapy, trauma, *etc*.). However, the unique challenges of providing medical nutrition therapy for patients receiving extracorporeal membrane oxygenation (ECMO) are rarely considered.[4,5]

Extracorporeal membrane oxygenation is a form of advanced life support for critically ill patients with severe cardiac or respiratory failure. Extracorporeal membrane oxygenation may be delivered in several different modes including venovenous (VV) ECMO for respiratory support, venoarterial (VA) ECMO for cardiac support or hybrid modes, and may also entail combinations of organ support devices. Extracorporeal membrane oxygenation may be used as a bridge to recovery, to intermediate or long-term mechanical support or to transplant, and may also be deployed to facilitate interhospital transfer of a critically ill patient.[6,7] Patients requiring ECMO may present with a severe acute illness with no prior comorbidity or have significant chronic health concerns and associated nutrition-related issues. Patients with severe acute illness have complex nutrition problems including acute changes in gastrointestinal motility and persistent catabolic states which vary with the presenting disease.[1] Further, patients are increasingly being supported with ECMO for extended periods of time (weeks to months) which impacts the nutrition treatment plan. These factors can have a significant impact on nutrition delivery and status over the course of admission. As survival following advanced therapies such as ECMO is improving, quality of survival is a critical focus; considering nutrition in the context of long-term recovery is vitally important and is the focus of ongoing research.[8]

The aim of this article was to assess the literature informing nutrition provision and practice for patients receiving ECMO and develop expert consensus recommendations to inform clinical practice.

Methodology

A group of international experts with experience managing the nutritional needs of patients receiving ECMO was convened by the Extracorporeal Life Support Organization (ELSO) to systematically develop consensus-based recommendations for nutrition therapy. Questions of interest were developed by the authors based on those included in guideline recommendations for general critically ill patients with modification specific to the context of patients receiving ECMO. Definitions of terminology used throughout this consensus recommendation document are outlined in Supplementary Table 1, Supplemental Digital Content, https://links.lww.com/ASAIO/B832.

Search

We conducted a systematic review of the literature on nutritional support in critical illness with a focus on patients receiving ECMO support. Search terms were predefined before database searches and adapted appropriately (Supplementary Appendix, Supplemental Digital Content, https://links.lww.com/ASAIO/B832, shows the databases searched and final MEDLINE Ovid SP search). The population of interest was critically ill, adult patients receiving ECMO; the intervention and comparison were any type of medical nutrition therapy and the outcomes of interest were any clinical or nutrition outcome reported in the papers of interest.

Studies were included if they met the following criteria:

1. Of any design (including reviews) but excluding abstracts
2. Published in the English language; and
3. Conducted in critically ill adult patients receiving ECMO (VA or VV) (≥18 years)
4. Reported on any element of medical nutrition therapy (enteral nutrition [EN], parenteral nutrition [PN], oral nutrition).

Quality Assessment

Two authors (D.E.B. and E.J.R.) independently assessed the article (excluding any type of review) quality using the National Institute for Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.[9] Overall recommendations were discussed to ensure consensus.

Evidence Level and Consensus Voting Process

All recommendations in this guideline are based on data from the available literature and developed by expert consensus. Each recommendation was listed and authors were asked to consider whether they agreed or disagreed (yes or no) with the recommendation based on the literature reviewed using an online blind voting process. If authors disagreed, they were able to provide comments explaining their reasoning, which are listed in Table 1.

Results

There were 331 records identified, with 41 articles included in the development of the consensus recommendations (Figure 1 and Table 1). There were 27 observational studies,[10–36] 11 review articles,[37–47] two guidelines,[4,5] and one proposed model.[48] No randomized controlled trials were retrieved.

Sixteen consensus-based recommendations were formulated for 10 clinical questions, of which 11 reached "strong consensus" (100%) and 5 "consensus" (87.5%). Where "100%" consensus was not reached, it was due to unclear evidence to inform this or variation in international practice (Table 2).

results. This publication reflects the information and expertise available at this time. New information will become available over time, but ELSO is under no obligation to provide updates. In no event will ELSO be liable for any decision made or action taken in reliance upon the information provided through this publication.

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Table 1. Summary of Included Literature

Author	Year	Design	Location*	Aim	Number of Patients	Number of VV ECMO *vs.* VA ECMO
Al-Dorzi *et al.*[37]	2020	Review	Saudi Arabia	Summarize the available evidence on the tolerance, safety, and efficacy of EN during the use of ECMO, prone positioning, and infusion of neuromuscular blockers	N/A—review	N/A—review
Banerjee *et al.*[38]	2017	Review	USA	To examine the nutritional implications of congestive heart failure, review the nutritional challenges of ECMO and VADs, summarize nutrition support recommendations for the complex cardiac patient, and highlight the importance of an interdisciplinary approach to implementing nutrition screenings and plans in this population	N/A—review	N/A—review
Bear *et al.*[39]	2018	Review	UK	To describe the current nutrition practices in patients receiving ECMO, detail research that is currently being undertaken, and list important research questions that require exploration in this field	N/A—review	N/A—review
Bear *et al.*[32]	2021	Retrospective analysis of prospectively collected data	UK	To assess skeletal muscle area and density at commencement of VV ECMO, their trajectory of change, and to investigate the relationship between skeletal muscle quantity and quality and clinical outcome, nutrition delivery, and physical function	215	VV ECMO = 215 VA ECMO = N/A
Brisard *et al.*[10]	2021	Retrospective, observational	France	To assess the nutritional route and impact of nutritional adequacy on the outcome of patients on ECMO. To identify opportunities to improve nutrition therapy during treatment in this specific population	112	VV ECMO = 26 VA ECMO = 86
Cresci *et al.*[40]	2012	Review	USA	To review the common challenges that exist with providing optimal nutrition therapy for the cardiothoracic critically ill patient	N/A—review	N/A—review
D'Alesio *et al.*[41]	2022	Review	Italy	To gather the current literature on nutrition during ECLS and to provide a summary of potential recommendations considering the following relevant topics: caloric intake in the acute and chronic phases, specific energy expenditure-monitoring tailored for ECLS, type of macronutrients needed, route for nutrition, and considerations for COVID-19 patients supported by ECLS	N/A—review	N/A—review
Davis *et al.*[42]	2021	Review	USA	To provide an overview of ECMO and changes in gut physiology during its use, outline the rationale for nutrition support in patients undergoing ECMO, and critically review existing literature for safety, tolerability, and efficacy of EN during ECMO	N/A—review	N/A—review
De Waele *et al.*[48]	2015	Prospective, observational	Belgium	To present a method to perform IC and propose a theoretical model for evaluating REE during ECMO. Preliminary experience with this approach in a patient is described	1	VV ECMO = 1 VA ECMO = N/A
De Waele *et al.*[11]	2018	Prospective, observational	Belgium	To measure REE according to our previously developed concept and technical setup for using IC in ECMO patients	7	VV ECMO = 3 VA ECMO = 4
Dresen *et al.*[43]	2023	Review	Germany	To provide evidence-based guidance on the use of medical nuttrition therapy in adult patients receiving ECMO in clinical practice to be considered as a basis for institutional standard operating procedures in routine clinical care	N/A—review	N/A—review
Elke *et al.*[5]	2019	Review	Germany	To provide clinicians with updated consensus-based recommendations for clinical nutrition in adult critically ill patients who suffer from at least one acute organ dysfunction requiring specific drug therapy and/or a mechanical support device (*e.g.*, mechanical ventilation) to maintain organ function	N/A—review	N/A—review
Farias *et al.*[44]	2015	Review	Chile	To provide a brief overview of the current literature regarding nutritional support during ECMO in adult patients, as no current guidelines address this issue	N/A—review	N/A—review
Ferrie *et al.*[12]	2013	Retrospective, observational	Australia	To assess the frequency of enteral nutrition intolerance among ECMO patients, to identify any barriers to successful nutrition delivery, and to investigate whether there is a difference between patients on VA ECMO and VV ECMO with regard to feeding tolerance	86	VV ECMO = 55 VA ECMO = 31
Gutierrez *et al.*[13]	2021	Retrospective, observational	USA	To examine the association between timing of initiation of enteral nutrition and neurologically favorable survival in patients suffering refractory VF/VT out of hospital cardiac arrest treated with prolonged CPR, ECPR, and targeted temperature management. In addition, feeding-associated safety outcomes are reported in relation to timing of feeding initiation	142	VV ECMO = N/A VA ECMO = 142

(*Continued*)

Table 1. Continued

Author	Year	Design	Location*	Aim	Number of Patients	Number of VV ECMO *vs.* VA ECMO
Hardy *et al.*[14]	2022	Retrospective, observational	UK	To describe the nutrition care, adequacy, and barriers to the provision of nutrition support to COVID-19 patients in critical care during the initial surge in a single center in the UK and to compare this in patients who received VV ECMO compared with those who did not. Additionally, the nutrition care and nutrition-related issues following step-down to the ward and following hospital discharge are described	252	VV ECMO = 58 VA ECMO = N/A
Hunt *et al.*[33]	2019	Prospective, observational	USA	To prospectively characterize the nutritional support of patients on ECMO at a single institution relative to support provided for non-ECMO patients	275	VV ECMO = 14 VA ECMO = 36
Karpasiti[45]	2021	N/A—review	UK	To provide an overview and critical appraisal of the most recent evidence concerning the nutritional management of adult critically ill patients requiring ECMO, to guide clinician practice and highlight key areas for future research. Further, it aims to identify potential differences between the nutritional management of patients receiving ECMO and other critically ill patient cohorts	N/A—review	N/A—review
Kim *et al.*[15]	2021	Retrospective, observational	Korea	To describe the nutritional support of people receiving ECMO in a tertiary academic medical center and identify factors that may confer benefits in outcomes	60	VV ECMO = 16 VA ECMO = 44
Lindberg *et al.*[36]	2020	Ex Vivo experiment using blood donations	Norway	To perform an *ex vivo* study to examine if any nutritional supplements given were adsorbed in the ECMO circuit	N/A ex vivo	N/A ex vivo
Lu *et al.*[17]	2018	Retrospective, observational	China	To evaluate the effects of nutritional therapy on prognosis and expect to establish a standard practice for the treatment of patients undergoing ECMO	102	VV ECMO = 25 VA ECMO = 77
Lu *et al.*[18]	2020	Retrospective, observational	China	To evaluate whether preoperative nutrition status at admission or postoperative nutrition treatment during admission for lung transplantation was linked to clinical outcomes	42	21 (type not specified)
Lukas *et al.*[16]	2010	Retrospective, observational	Australia	To describe the use, methods, and adequacy of nutritional support in a consecutive group of patients receiving ECMO; to determine differences between the periods during and after ECMO support; and to determine differences in nutritional adequacy between ECMO survivors and ECMO nonsurvivors	48	VV ECMO = 13 VA ECMO = 35
MacGowan *et al.*[19]	2019	Retrospective, observational	UK	To describe nutrition practices in a single center providing VV ECMO to assess the timing and adequacy of energy and protein delivery through gastric, jejunal, and parenteral routes, GI complications during VV ECMO therapy, and the difference in delivery of energy and protein during and after VV ECMO. Further, to investigate the association of nutrition support adequacy with clinical outcome	203	VV ECMO= 203 VA ECMO= N/A
Miessau *et al.*[20]	2013	Retrospective, observational	USA	To investigate whether early nutritional support has any impact on survival among patients on ECMO	59	VV ECMO = 12 VA ECMO = 47
Minami-Takano *et al.*[21]	2019	Retrospective, observational	Japan	To expand the clinical application of this novel and easy-to-calculate nutritional index for the most critical populations, we evaluated triglycerides, total cholesterol, and body weight as a potential nutritional index as well as an indicator for mortality in hemodynamically unstable critical patients who require the placement of percutaneously implantable mechanical circulatory support devices with or without VA ECMO	439	VV ECMO = N/A VA ECMO = 71
Muller *et al.*[22]	2023	Prospective, observational	Germany	To evaluate the accuracy and potential strengths or weaknesses of the Quantum Diagnostics System and its measuring approach under clinical routine settings in venovenous ECMO (VV ECMO) therapy	9	VV ECMO = 9 VA ECMO = N/A
Ohbe *et al.*[23]	2018	Retrospective, observational	Japan	To compare the mortality and morbidity of patients receiving early EN and undergoing VA ECMO for more than 2 days for cardiogenic or obstructive shock	1769	VV ECMO = N/A VA ECMO = 1,769
Ong *et al.*[24]	2022	Retrospective, observational	USA	To describe a method to calculate REE in a pilot study of ECMO patients with ARDS directly from the ventilator and ECMO circuits without requiring IC. Second, using continuous waveform technology, to determine when pulmonary contribution to meaningful gas exchange occurs requiring consideration of ventilator contribution to REE	10	VV ECMO = 10 VA ECMO = N/A

(*Continued*)

Table 1. Continued

Author	Year	Design	Location*	Aim	Number of Patients	Number of VV ECMO *vs.* VA ECMO
Park *et al.*[25]	2020	Retrospective, observational	Korea	To evaluate the relationship between nutritional supply and clinical outcomes in patients undergoing VA ECMO. Additionally, to measure the nutritional status of energy and protein intake and analyzed the reasons why patients on VA ECMO did not receive appropriate amounts of nutrition and the complications that occurred after providing nutritional support	41	VV ECMO = N/A VA ECMO = 41
Pelekhaty *et al.*[26]	2020	Prospective, observational	USA	To investigate protein catabolism during VV ECMO support at a single high-volume center and to assess whether current nutrition recommendations were adequate to achieve nitrogen equilibrium in these patients	16	VV ECMO = 16 VA ECMO = N/A
Pelekhaty *et al.*[27]	2020	Prospective, observational	USA	To investigate the adequacy of current recommendations for protein provision measured by nitrogen equilibrium in adults on VV ECMO.	29	VV ECMO = 29 VA ECMO = N/A
Reintam Blaser *et al.*[4]	2017	Review	Estonia	To provide evidence-based guidelines for earlyEN during critical illness	N/A—review	N/A—review
Ridley *et al.*[28]	2015	Prospective, observational	Australia and New Zealand	To perform a multicenter study in Australia and New Zealand to describe current nutrition delivery practices and to identify barriers to nutrition therapy in patients receiving VV or VA ECMO	107	VV ECMO = 42 VA ECMO 65
Scott *et al.*[28]	2004	Retrospective, observational	USA	To evaluate the center's experience with early enteral nutrition in adult patients receiving VV ECMO for severe respiratory failure in order to characterize the safety and tolerance of enteral nutrition in this patient population	27	VV ECMO = 27 VA ECMO = N/A
Stoppe *et al.*[46]	2018	Review	Germany	To provide an overview on recently published data and highlight specific topics regarding metabolic and nutritional support in patients with ECLS and VAD	N/A—review	N/A—review
Tatucu-Babet *et al.*[34]	2023	Prospective, observational	Australia and New Zealand	To assess the feasibility of measuring EE in patients receiving VA ECMO using a modified indirect calorimetry protocol. Secondary objectives were to report measured EE in patients receiving VA ECMO and to compare values with predictive equation estimates and to control critically ill patients not receiving ECMO	21	VA ECMO = 21 (16 included in EE analysis), VV = N/A
Ulerich *et al.*[47]	2015	Review	USA	To assist the nutrition care provider in caring for the transplant patient undergoing ECMO support	N/A—review	N/A—review
Umezawa Makikado *et al.*[29]	2013	Prospective, observational	Spain	To evaluate the tolerance and safety of EN in a consecutive group of patients receiving VA ECMO for severe cardiopulmonary failure	7	VV ECMO = N/A VA ECMO =7
Visvalingam *et al.*[31]	2022	Retrospective, observational	Australia	To investigate the association between clinical and biochemical factors predictive of gastrointestinal and liver dysfunction with nutrition adequacy in the first 5 days of ECMO	176	VV ECMO = 57 VA ECMO = 119
Wollersheim *et al.*[30]	2018	Prospective, observational (protocol, feasibility, and pilot)	Germany	To introduce a new protocol, which allows the measurement of EE in patients with ECLS. Second, to compare the new protocol with the most common equations for the estimation of caloric targets in ARDS patients. Finally, to compare the EE of ARDS patients with VV ECMO to ARDS patients without ECMO, and assess the impact of the VV ECMO blood flow.	40	VA ECMO = N/A VV ECMO = 20

ARDS, Acute Respiratory Distress Syndrome; CHF, Congestive Heart Failure; CPR, Cardiopulmonary Resuscitation; COVID-19, coronavirus disease 2019; ECLS, extracorporeal life support; ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation; EEN, early enteral nutrition; EN, enteral nutrition; GI, Gastrointestinal; IC, indirect calorimetry; REE, resting energy expenditure; VA, venoarterial; VAD, ventricular assist device; VF, ventircular Fibrillation; VT, ventricular tachycardia; VV, venovenous.

Full details of the results, including the narrative informing the recommendations and quality assessment, are in the Supplementary Appendix, Supplemental Digital Content, https://links.lww.com/ASAIO/B832. The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) flowchart for study selection is in Figure 1.

Quality

Of the 26 studies eligible for quality assessment, 24 (92.3%) were rated as "fair,"[10–22,24–28,30–35] 1 (3.8%) rated as "good,"[23] and 1 (3.8%) rated as "poor"[29] (see Supplementary Appendix, Supplemental Digital Content, https://links.lww.com/ASAIO/B832, for full details).

Clinical Questions With Recommendations

1. Should dietitians be included as part of the critical care multidisciplinary team managing patients receiving ECMO?

We recommended that a dietitian (or clinician with specialist clinical nutrition knowledge) is included as a key member of the critical care multidisciplinary team managing patients receiving ECMO (strong consensus 100%).

- Patients receiving ECMO pose metabolic and nutritional challenges and a dietitian is best placed within the multidisciplinary care team to manage this, including being able to undertake a thorough nutrition assessment.[49]
- In countries where specialist intensive care unit (ICU) dietitians do not practice, an identified nutrition specialist of another profession (*e.g.,* commonly a nursing or medical professional) is recommended.

2. Should patients receiving ECMO support receive a nutrition assessment?

We recommend that a full nutrition assessment, including physical assessment, be performed by a dietitian (or clinician with specialist clinical nutrition knowledge) within 72 hours of admission and weekly thereafter (strong consensus 100%).

- Although a full nutrition assessment, including physical assessment, is an essential component of the nutrition management of any critically ill patient, there is no gold standard,[50] including in patients receiving ECMO.
- Only one study has investigated malnutrition status on admission to ICU in an ECMO population, where the Subjective Global Assessment was used.[12] Over 90% of the population studied (N = 86) were considered normally nourished.
- Subjective global assessment or Global Leadership Initiative on Malnutrition (GLIM) criteria are acceptable methods to use[50,51] with consideration of the potential to underestimate nutrition risk or malnutrition status on ICU admission or commencement of ECMO due to factors such as a younger age, altered physiology,[39] duration of ICU admission before commencing ECMO, and the projected long ICU length of stay in most ECMO patients.
- If a specific tool is not used, factors such as pre-ICU length of stay, projected ICU length of stay, and results from a physical assessment should be considered together.

3. Should all patients receiving ECMO support be considered for medical nutrition therapy?

We recommend all patients are considered for medical nutrition therapy regardless of pre-existing nutrition status due to the metabolic consequences of ECMO, the associated conditions requiring ECMO treatment (critical illness) and the duration of pre-ICU, projected ICU, and hospital length of stay for those who survive (strong consensus 100%).

- A large proportion of patients, especially those where ECMO is commenced as a bridge to transplant/long-term mechanical support, are already malnourished at the time of ECMO initiation due to pre-existing chronic health issues, including chronic heart and/or respiratory failure.[46] Other considerations include the inflammatory and catabolic impact of ECMO,[26,27,52] the diseases that lead to a requirement for ECMO therapy, as well as prior and predicted duration of both ICU and hospital stay and the duration of ECMO for patients who survive[44] which may all exacerbate malnutrition.
- Delaying commencement of medical nutrition therapy (even in patients who are premorbidly well nourished) may further exacerbate complications and aggravate the well-described loss of muscle mass.[32,52]

4. Should all patients receiving ECMO receive early EN?

We recommend early EN is considered for patients receiving ECMO where EN is not contraindicated (strong consensus 100%).

We recommend that delaying or commencing EN at low dose is considered in patients with uncontrolled severe shock with daily review to prevent prolonged underfeeding (strong consensus 100%).

- The use of early EN in patients receiving ECMO is supported in the European Society of Intensive Care Medicine (ESICM) clinical practice guidelines[4,5] and observational, retrospective studies retrieved in the current search support the safety and feasibility.[10,12,15,19,25,28,33]
- Current data from patients receiving ECMO also indicate some clinical benefit to the provision of early EN with one observational study reporting that early EN, compared with late EN in patients receiving VA ECMO for cardiogenic or obstructive shock was associated with a significantly lower in-hospital and 28 day mortality[23] and early EN was associated with reduced in-hospital mortality in another (ECMO type not specified).[15]
- Overall, the cumulative current evidence suggests that early EN is feasible and safe in patients receiving ECMO, but dose (energy and protein) restriction should be implemented in the very acute phase and in patients with uncontrolled shock until hemodynamic stability has been achieved.[1,3,4,53]
- The effects of prolonged underfeeding remain unknown and therefore daily review is strongly recommended in those on an initial restricted feeding regimen.

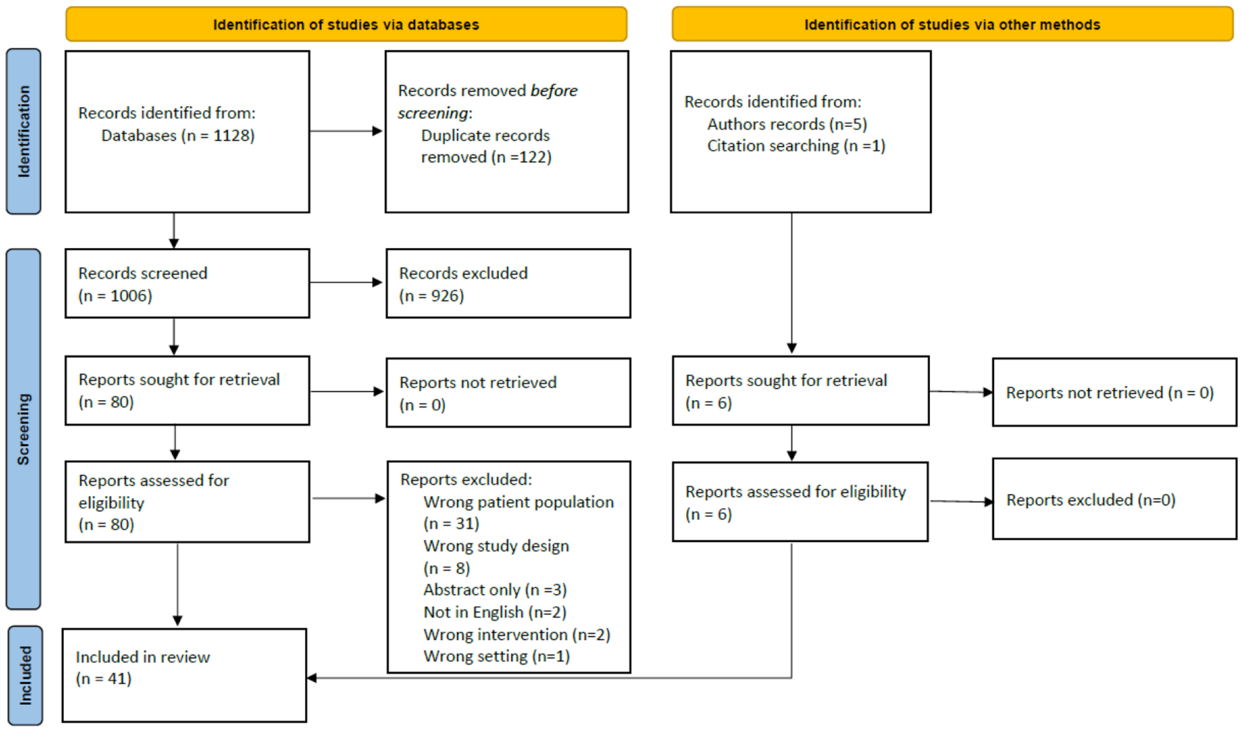

Figure 1. PRISMA flowchart for study selection. PRISMA, Preferred reporting items for systematic reviews and meta-analysis

5. How should gastrointestinal intolerance be managed in patients receiving ECMO?

We recommend the use of prokinetics for delayed gastric emptying, defined using gastric residual volume (GRV) cutoffs locally, but not less than 250 ml 4 hourly (consensus 87.5%).

We recommend regular review of laxative dose so as not to achieve excessive stool output >1 L/day (strong consensus 100%).

We recommend the use of postpyloric feeding tubes or, in the absence of a postpyloric feeding tube insertion service, PN, for persistent delayed gastric emptying refractory to prokinetics (strong consensus 100%).

- Enteral feeding intolerance (EFI) is frequently cited as a complication in patients receiving ECMO, with the most commonly reported reasons defining EFI being elevated GRVs, diarrhea, ileus, and bowel ischemia.[10,12–16,19,25,28,33,35]
- Elevated GRVs are reported to be a major barrier to achieving target energy and protein delivery for those receiving ECMO.[14,19]
- There is no standardized approach for the management of delayed gastric emptying in the general critically ill population; however, guidelines recommend the use of prokinetics, including metoclopramide or erythromycin.[1]
- An alternative approach to the management of delayed gastric emptying is postpyloric feeding.[19] However, the logistical issues associated with placement of postpyloric feeding tubes, especially if radiological or endoscopic guidance is required, must be considered. Bedside approaches to the placement of feeding tubes may be timelier,[54] although this technique is not available in every institution.
- PN (supplemental or total) use is an acceptable alternative to EN in centers without ready access to postpyloric feeding tubes[12,28] and is supported in the recent American Society for Parenteral and Enteral Nutrition (ASPEN) guideline update.[2]
- Switching to a more concentrated feed to reduce the volume of delivery is not recommended, as this has been shown to increase the prevalence of Gastrointestinal dysfunction rather than improve it.[55]
- Laxatives are recommended to achieve stool output of no more than 1 L with a balance between prevention of ileus and the adverse consequences of high stool output including fluid and electrolyte deficiencies.

6. Under what circumstances should PN be used in patients receiving ECMO?

We recommend that the ICU length of stay (LOS) before commencing ECMO is considered when deciding on the use of PN and that PN be considered following 72 hours of intolerance to EN or where enteral access cannot be achieved (strong consensus 100%).

- No studies have compared EN and PN in patients receiving any type of ECMO or investigated the timing of commencing PN in patients not tolerating EN. However, observational studies report using PN, either alone or in combination with EN, in 2–30% of patients[10,12,14,16,19,20,33] and one study reports using PN alone on 111 study days (7%) and EN combined with PN on 52 study days (3%).[28]
- In patients receiving ECMO and either not tolerating full EN, having contraindications to EN or not having EN access, the use of PN (as a sole source of nutrition or as a supplement to EN; SPN) should be initiated on a

Table 2. Summary of Recommendations and Consensus Comments

Recommendation	Agreement (%)	Personal Comments/Rationale for Disagreement
We recommended that a dietitian is included as a key member of the critical care multidisciplinary team managing patients receiving ECMO	100	n/a
We recommend that a full nutrition assessment, including physical assessment, be performed by a dietitian (or clinician with specialist clinical nutrition knowledge) within 72 hours of admission and weekly thereafter	100	n/a
We recommend all patients are considered for medical nutrition therapy regardless of pre-existing nutrition status due to the metabolic consequences of ECMO, the associated conditions requiring ECMO treatment (critical illness), and the duration of pre-ICU, projected ICU, and hospital LOS for those who survive	100	n/a
We recommend early EN is considered for patients receiving ECMO, where EN is not contraindicated	100	n/a
We recommend that delaying or commencing EN at low dose is considered in patients with uncontrolled severe shock with daily review to prevent prolonged underfeeding	100	n/a
We recommend the use of prokinetics for delayed gastric emptying, defined using GRV cutoffs locally, but not less than 250 ml 4 hourly	87.5	The cutoffs used can be controversial
We recommend regular review of laxative dose so as not to achieve excessive stool output >1 L/day	100	n/a
We recommend the use of postpyloric feeding tubes or PN in the absence of a postpyloric feeding tube insertion service for persistent delayed gastric emptying refractory to prokinetics	100	n/a
We recommend that the ICU LOS before commencing ECMO is considered when deciding on the use of PN and that PN be considered following 72 hours of intolerance to EN or where enteral access cannot be achieved	100	n/a
We recommend monitoring of triglyceride levels and visual inspection of the membrane oxygenator for clotting when receiving PN and to consider lipid-free PN if concerns arise	87.5	There is no current ICU guideline supporting the use of lipid-free parenteral nutrition
In the absence of a standardized, validated protocol for the use of IC in patients receiving ECMO, a weight-based formula (25 kcal/kg/BW/day) should be used to calculate energy targets for simplicity	100	n/a
We recommend aiming for <70% of estimated or measured energy targets for the first 3 days of ECMO, with a progressive increase to target after this and avoiding prolonged underfeeding	87.5	The cutoff seems to be chosen randomly; I would prefer this not to be set in metrics in the absence of evidence
We recommend aiming for <70% of protein targets for the first 3 days of ECMO and progressively increasing to target after this, avoiding prolonged underfeeding	87.5	There is limited evidence on the timing for reaching 100% of the target protein dose in critically ill and ECMO patients. It is inevitable that protein underfeeding will occur over the first 72 hours if we are intentionally hypocalorically underfeeding. However, based on limited evidence, I don't think that intentionally aiming for <70% protein targets can be confidently recommended. If 100% protein targets can be achieved alongside hypocaloric feeding (*i.e.,* using a low kcal/high protein formulation), then this should not be discouraged
We recommend aiming for a protein dose of no more than 1.3 g/kg/day, especially in those patients with acute kidney injury or high severity of illness at admission	87.5	If we agree that there is a higher protein need in CRRT because of loss by the filter, we can expect the same to happen in ECMO
We recommend that monitoring of medical nutrition therapy for patients receiving ECMO should be under guidance of a critical care dietitian or other clinician with specialist clinical nutrition knowledge. Monitoring should include nutrition status, refeeding syndrome, energy and protein balance, metabolic tolerance (*e.g.,* blood glucose levels and insulin requirements), and gastrointestinal tolerance (measurement of GRVs and abdominal pathology)	100	n/a
We recommend if oral intake is between 50 and 75% of target energy and protein for 72 hours, despite maximal oral nutrition therapy strategies, that escalation to EN (alone or as a supplement to oral intake) be strongly considered to prevent further nutrition decline	100	n/a

The strength of consensus was based on that included in the European Society for Parenteral and Enteral Nutrition (ESPEN) guidelines[1]; strong consensus (agreement of >90% of participants), consensus (agreement of >75%–90% of participants), majority agreement (≥50%–75% of participants), no consensus (agreement of <50% of the participants).

CRRT, continuous renal replacement therapy; ECMO, extracorporeal membrane oxygenation; EN, enteral nutrition; GRV, gastric residual volume; ICU, intensive care unit; LOS, length of stay; PN, parenteral nutrition.

case-by-case. Important considerations are the nutrition status of the patient assessed within 3 days of commencing ECMO, the duration of ICU stay before commencing ECMO, the predicted ECMO and subsequent ICU LOS, and the anticipated time to commence EN.
- This recommendation should be used in line with recommendation 7 regarding the assessment of nutrition risk in ECMO patients.

We recommend monitoring of triglyceride levels and visual inspection of the membrane oxygenator for clotting when receiving PN and to consider lipid-free PN if concerns arise (consensus 87.5%).

- The potential for lipid infiltration into the oxygenator and resultant circuit failure or increased risk of membrane thrombus formation need to be considered.[56]
- Recommendations from one group of authors suggest that intravenous lipid administration should not exceed 10 ml/kg to reduce the risks involved[56] and others suggest that a cutoff value of 3 mmol/L for plasma triglycerides should be used to inform decisions for lipid-free PN based on their local practice.[39]
- While strong recommendations are impossible to provide in the context of limited evidence, it is reasonable to suggest monitoring the oxygenator and measuring triglyceride levels twice weekly in patients receiving ECMO and PN and to limit intravenous lipid provision (including propofol) where the circuit is thought to be a risk. In this instance, lipid-free PN may be considered with provision of weekly lipids and daily fat-soluble vitamin administration to prevent the development of essential fatty acid deficiency.

7. How should energy targets be calculated in patients receiving ECMO and what dose should be achieved?

In the absence of a standardized, validated protocol for the use of indirect calorimetry (IC) in patients receiving ECMO, a weight-based formula (25 kcal/kg/BW/day) should be used to calculate energy targets for simplicity (strong consensus 100%).

- IC is considered the gold standard for measuring energy expenditure (EE) in critically ill patients.[1,2] However, gas exchange occurring within the extracorporeal circuit may limit its feasibility and accuracy in patients receiving ECMO.[39]
- To date, four techniques have been described to measure EE in ECMO patients,[22,24,30,34,48] each with limitations (full details specified in the Supplementary Appendix, Supplemental Digital Content, https://links.lww.com/ASAIO/B832).
- Most studies of clinical practice in ECMO describe the main equation used to be 25 kcal/kg/BW/day.[14,19,20,29,32] However, as observed in the general critically ill population, measured EE using IC of individuals receiving ECMO varies daily when expressed in kcal/kg/BW/day.[30,34,48] This suggests that EE may potentially depend on factors such as underlying disease, ECMO duration, gas flow, and lung functionality; however, these assumptions require confirmation in larger studies.
- Given the lack of adequate evidence to inform the optimal energy dose for ECMO patients, applying general ICU nutrition guideline recommendations[1,2] to estimate energy targets is a practical approach; however, use of clinical judgement and expertise in clinical nutrition is paramount.

We recommend aiming for <70% of estimated or measured energy targets for the first 3 days of ECMO, with a progressive increase to target after this and avoiding prolonged underfeeding (consensus 87.5%).

- Achieving <70% of estimated energy targets in the subjective "acute" or "early phase" of critical illness with progressive increase in rate appears reasonable, which requires regular monitoring to prevent prolonged underfeeding.
- Extracorporeal membrane oxygenation patients often experience prolonged ICU stays and significant catabolism, underscoring the importance of regular, monitoring to ensure adequate nutrition and the avoidance of prolonged underfeeding.
- Higher energy targets may be appropriate for mobile patients or those off mechanical ventilation,[39] although no studies currently exist exploring measured EE in ambulatory ECMO patients.

8. How should protein targets be calculated in patients receiving ECMO and what dose should be achieved?

We recommend aiming for a protein dose of no more than 1.3 g/kg/day, especially in those patients with acute kidney injury or high severity of illness at admission (consensus 87.5%).

- The optimal dose of protein to provide in critically ill patients is unknown and this includes patients receiving ECMO. Nitrogen balance studies performed in ECMO patients suggest that protein requirements in both obese and nonobese patients may be higher than the current recommendations.[27,57]
- The protein recommendation for general critically ill patients in international guidelines ranges between 1.2 and 2.5 g/kg/day based on their individual needs,[1] but recent data suggest that amounts above 1.3 g/kg/day may be harmful in patients with high severity of illness and Acute Kidney Injury (AKI).[58]
- Given that no randomised controlled trial (RCT) data exist for protein delivery in patients receiving ECMO and the recent results of the EFFORT Protein Trial,[58] the target for protein delivery should be as per current guideline recommendations (1.3 g/kg/day)[1] and probably lower in those patients with development of acute kidney injury and more severe illness, particularly in the acute phase of illness.

We recommend aiming for <70% of protein targets for the first 3 days of ECMO and progressively increasing to target after this, avoiding prolonged underfeeding (consensus 87.5%).

- Reaching protein targets in patients receiving ECMO can be difficult, particularly if energy provision is reduced to account for propofol, and underfeeding is common.[19,28]
- The optimal timing of reaching the target protein dose is unknown, but given recommendations for hypocaloric

feeding early in critical illness, underdosing protein will be inevitable.

- Effort should be made to avoid prolonged protein underfeeding due to the risk of muscle wasting, the unknown effect on long-term outcome, and the known association between increased muscle wasting and worse clinical outcome in critical illness.

9. How should medical nutrition therapy be monitored in patients receiving ECMO?

We recommend that monitoring of medical nutrition therapy for patients receiving ECMO should be under guidance of a critical care dietitian or other clinician with specialist clinical nutrition knowledge. Monitoring should include nutrition status, refeeding syndrome, energy and protein balance, metabolic tolerance (*e.g.,* blood glucose levels and insulin requirements), and gastrointestinal tolerance (measurement of GRVs and abdominal pathology) (strong consensus 100%).

- There are no studies investigating the effectiveness of monitoring the provision and tolerance of medical nutrition therapy in any group of critically ill adults on outcome.
- As an accompaniment to the European Society for Parenteral and Enteral Nutrition (ESPEN) guidelines for medical nutrition therapy in the ICU, a position paper providing recommendations for monitoring medical nutrition therapy and metabolism is available.[59] Recommendations from this position paper have been considered in the recommendations provided here with caveats for the ECMO population made as per the clinical expertise of this guidelines group.

10. How should nonventilated patients receiving ECMO be managed?

We recommend if oral intake is between 50 and 75% of target energy and protein for 72 hours, despite maximal oral nutrition therapy strategies, that escalation to EN (alone or as a supplement to oral intake) be strongly considered to prevent further nutrition decline (strong consensus 100%).

- Awake patients, especially if not mobile or feeling nauseous, can have reduced appetite, difficulty in positioning for eating, and the use of high flow oxygen can dry the oral mucosa, making chewing and swallowing difficult. They may also be less tolerant of nasogastric tubes. These factors mean that malnutrition can quickly develop.
- Evidence from the general critically ill population informs of some of the anticipated issues with oral intake during critical illness and recovery[60–62] and underscores the need for careful consideration for the continued requirement of EN while oral nutrition is established.

Conclusions

There are limited high-level data to inform nutrition practice in adult patients receiving ECMO. However, these consensus recommendations have been developed using the available observational data, relevant studies of nutrition in general critically ill patients and the clinical expertise of those working in high-volume ECMO centers to guide nutrition practices with the aim of improving both short and long-term patient outcomes. The importance of individualized nutrition assessment, treatment, and ongoing monitoring is imperative in this patient cohort. It is recommended that there is a recognized member of the multiprofessional team with nutrition expertise (*e.g.,* ideally a dietitian or other professional with an interest or additional training in critical care nutrition) who can lead the nutrition service for these patients. These recommendations are based on the best available evidence at the time of writing, but clearly highlight the need for more focused nutrition research in this patient group.

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