Clinical Nutrition xxx (xxxx) xxx

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Covid-19

Nutrition support practices across the care continuum in a single centre critical care unit during the first surge of the COVID-19 pandemic — A comparison of VV-ECMO and non-ECMO patients

Georgia Hardy [a, b], Luigi Camporota [b], Danielle E. Bear [a, b, *]

[a] Department of Nutrition and Dietetics, Guy's and St Thomas' NHS Foundation Trust, London UK
[b] Department of Critical Care, Guy's and St Thomas' NHS Foundation Trust, London UK

ARTICLE INFO

Article history:
Received 14 June 2022
Accepted 29 August 2022

Keywords:
Nutrition
Critical care
COVID-19
ARDS
Enteral feeding
ECMO

SUMMARY

Background & aims: Critically ill patients with COVID-19 are at high nutrition risk. This study aimed to describe the nutrition support practices in a single centre critical care unit during the initial surge of the COVID-19 pandemic. Practices were explored from ICU admission to post-ICU follow-up clinic and patients who received veno-venous extra-corporeal membrane oxygenation (VV-ECMO) were compared to those who did not.

Methods: This retrospective observational study included COVID-19 positive, adult ICU patients who were mechanically ventilated for ≥72 h. Data were collected from ICU admission until the time of post-ICU clinic. For in-ICU data, results are compared between patients who did and did not receive VV-ECMO.

Results: 252 patients were included (VV-ECMO n = 58). Adequate energy and protein was delivered in 193 (76.6%) patients during their ICU admission with no differences between those who did and did not receive VV-ECMO (44 (75.9%) *vs.* 149 (76.8%)). Parenteral nutrition only being required in 12 (4.8%) patients. Following stepdown to the ward 77 (70%) patients required ongoing enteral nutrition support, and 74 (66.7%) required a texture modified diet or were NBM. Following hospital discharge, nearly a third of ICU survivors (28.4%) were referred for dietetic input. The most common referral reason was loss of weight. Breathlessness and fatigue were the most commonly reported nutrition impact symptoms experienced following hospital discharge.

Conclusion: Results show it is possible to reach nutritional adequacy for most patients and that neither VV-ECMO nor proning were barriers to nutritional adequacy. Nutritional issues for patients who were critically ill with COVID-19 persist following stepdown to ward level and into the community and strategies to manage this require further investigation.

1. Introduction

The Coronavirus disease 2019 (COVID-19) pandemic led to worldwide surge expansion of critical care requirement and capacity. This included the provision of critical care outside of traditional intensive care units (ICUs) leading to challenges in the provision of care — including nutrition assessment and delivery to these patients [1].

Nutrition is a mainstay of supportive care for critically unwell patients. Multiple guidelines were rapidly published in relation to the nutrition care of COVID-19 patients in critical care settings [2—5] with recommendations extrapolated from non-COVID-19 respiratory failure aetiologies.

The prevalence of malnutrition in critically ill COVID-19 positive patients at ICU admission ranges from 18% to 60% using Global Leadership Initiative on Malnutrition (GLIM) criteria [6,7] and a proportion of these patients have a hypermetabolic phenotype [8—10]. Moreover, nutritional status declines in this patient group throughout the hospital stay [11—13]. This is associated with both increased length of stay and mortality [7]. Given the prognostic importance of nutritional status in patients with severe COVID-19, the prevention of nutritional decline should be a prioritized.

Initial observational studies on nutrition related issues and care patients received during the first surge of the COVID-19 pandemic

* Corresponding author. Principal Critical Care Dietitian, Dept of Nutrition and Dietetics, St Thomas' Hospital, Westminster Bridge Rd, London SE17EH, UK.
E-mail address: Danielle.Bear@gstt.nhs.uk (D.E. Bear).

https://doi.org/10.1016/j.clnu.2022.08.027
0261-5614/

in critical care have recently been published [14–16]. Findings suggest feeding intolerance is common [15], though may not significantly affect nutritional adequacy early in ICU admission [16]. An association between early caloric adequacy and decreased ICU mortality has also been reported [14].

With the increase in severe respiratory failure associated with COVID-19, there was a parallel increase in the use of veno-venous extra-corporeal membrane oxygenation (VV-ECMO).

Whilst ECMO is reserved for the most severely unwell patients, to date more than 13,000 COVID-19 patients world-wide have received ECMO [17]. Patients receiving both VV and VA (veno-arterial) ECMO have been reported to have specific nutritional issues including high rates of enteral feeding intolerance [18] and poor nutrition provision during ICU stay [19,20]. Only one study (in abstract form) comparing provision of nutrition to VV-ECMO compared with non-ECMO exists with slightly higher prescribed versus delivered feeds in the VV-ECMO patients being reported, though the reasons behind this difference are not examined [21].

There is a growing interest in nutrition in the post-ICU period, with a move towards considering the whole trajectory of care for patients who have been critically unwell, given this may be a pertinent period for nutrition intervention when patients move towards catabolism and rehabilitation [22]. Nutritional intake in this group following step-down to the ward is poor [23], and rates of dysphagia are high [12,24].

There have been a number of studies published regarding nutrition in patients with COVID-19 however there remains many unanswered questions. There are very few studies which look at significant numbers of patients who received VV-ECMO compared to those who did not, the nutritional issues experienced in these patient groups not only during ICU admission, but following ICU and hospital discharge. The ability to provide adequate nutrition care to these patients during a time of immense pressure to healthcare systems internationally has been a unique challenge from which there is much to learn.

The aim of this study was 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 centre in the UK and to compare this in patients who received VV-ECMO compared to those who did not. Additionally, the nutrition care and nutrition-related issues following step-down to the ward and following hospital discharge are described.

2. Material & methods

2.1. Study design

This was a retrospective observational study undertaken at a single UK NHS trust between 01/03/2020 to 30/06/2020. The critical care unit is a severe respiratory failure centre with an ECMO service regulate by NHS England [25]. All adult (18 years of age and over) patients who were admitted to the ICU with a positive COVID-19 PCR test and who were mechanically ventilated for 72 h or longer were included. Those who were previously COVID positive but had further negative tests prior to ICU admission were excluded.

Local ethical approval was received (reference number 11023) with the need for informed consent waived.

2.2. Data collection

Data was collected from electronic medical records, starting from the time of ICU admission. Inpatient data collection continued up until transfer to an external hospital, hospital discharge or death. Outpatient data were collected for any included subject who attended the local post-ICU recovery clinic following hospital discharge.

Inpatient data collected included the following information for critical care admission: demographic information, APACHE II (Acute Physiology and Chronic Health Evaluation II) and SOFA (Sepsis-related Organ Failure Assessment) score on day of ICU admission, anthropometry, time to commencement of enteral (EN) or parenteral nutrition (PN), nutritional adequacy (as defined below), use of prokinetic drugs, feed tolerance (high gastric residual volumes (GRV) defined as >300 ml), dietetic input and type of nutrition support received. Outpatient information collected included symptoms that were deemed *a priori* to impact on nutrition intake or status or be a consequence of poor nutritional intake or status and reasons for dietetic referral.

2.3. Nutrition support

Enteral nutrition was commenced as per local hospital policy with enteral feed target rate set depending on body weight and followed for the first 48–72 h. Following Dietetic assessment (aim within 48–72 h of admission), enteral formula and target rate were individualised by the dietitian. An enteral modular protein supplement was used when enteral nutrition formulas were inadequate to meet protein targets. Enteral and parenteral nutrition support were prescribed continuously over 24 h as per local policy.

Energy targets were set by dietitians using either the Penn State Equation 2003 b [26] or 25 kcal/kg using an adjusted body weight for those with BMI >30 kg/m^2. For those receiving VV-ECMO, all were calculated using 25 kcal/kg (using an adjusted body weight if BMI >25 kg/m^2. Adjustment was calculated by calculating ideal body weight and adding 50% of excess weight if BMI was 25.1–29.9 kg/m^2, or 25% of excess weight if BMI >30 kg/m^2).

Protein targets were set at a minimum of 1.2 g/kg/day, with increases depending on clinical condition (i.e. continuous renal replacement therapy, obesity, etc.). Actual weight was used for this calculation for patients with BMI <25 or using an ideal bodyweight for those with a BMI >25 kg/m^2.

Adequacy of delivered energy and protein were calculated daily for the length of critical care admission. Energy provision included calories from non-nutrition sources including propofol and intravenous (IV) glucose. Underfeeding was defined as receiving <80% of nutritional targets and overfeeding was defined as receiving >110% energy targets. Discarded GRVs were not taken into account.

Daily energy and protein delivered were compared with the estimated target that day. If targets were expressed as a range, the midpoint of the range was used. For the first and last day of ICU admission, nutritional targets were calculated as a proportion of a 24-h period based on the time of admission, and the time of critical care discharge or death.

2.4. Statistical analysis

Categorical data are presented as n (%), continuous data as mean (standard deviation [SD]) for normally distributed data and median (interquartile range [IQR]) for non-normally distributed data. Assumptions for normality were assessed using Kolmogorov–Smirnov One–Sample test.

Categorical data were compared between groups using Chi-squared test or Fisher's exact test where cells contain counts of less than 5. Continuous data, which was not normally distributed, were compared between groups using the Mann–Whitney U test. Where data are normally distributed, the independent samples t-test was used. Significance was considered where $p < .05$.

Analysis were performed using SPSS 26 (IBM Corp. Armonk, NY) and Graphpad Prism 8.

3. Results

In total, 338 patients were screened for eligibility with 252 included in the final analysis, as detailed in Fig. 1. Of these 252 patients, 58 received VV-ECMO. Baseline demographics are reported in Table 1. Patients who received VV-ECMO were younger (45.0 (8.5) vs. 56.0 (12.5) years; $p = .000$), received proning on fewer occasions (1.5 (1.0–3.5) *vs.* 3.0 (2.0–5.0) $p = .000$), but received sedation for longer (18.0 (11.8–25.5) *vs.* 13.0 (8.0–21.0) $p = .011$). Length of hospital stay was also longer for patients requiring VV-ECMO (52.0 (27.0–65.0) *vs.* 27.0 (14.3–49.0) $p = .000$).

3.1. Route of feeding, time to feeding and adequacy of nutrition support

Data relating to the route of feeding, time to feeding and the adequacy of nutrition support can be seen in Table 2. Naso-gastric (NG) feeding was the most common route of feeding for all patients (251 (99.6%)) with only one patient never receiving NG feeding. Parenteral nutrition was used in only 12 (4.8%) patients. More patients who received VV-ECMO required post-pyloric feeding at some point during their admission than non-ECMO patients (10 (17.2%) *vs.* 4 (2.1%), $p = .000$).

The median (IQR) time taken to commence feeding from ICU admission (EN or PN) was 9.6 h (6.5–14.0 h) with no significant difference between those who received VV-ECMO and those who did not (10.4 h (8.0–15.0 h) *vs.* 10.4 h (8.0–15.0 h), $p = .057$). The median energy delivery from all sources (EN, PN, propofol, IV glucose) compared to target was 96.4% (88.5–101.6%) and for EN and PN alone was 87.1% (77.9–93.4%). Median protein delivery compared to target was 92.2% (81.4–100.5%). Data are similar between those who received VV-ECMO and those who did not, except for energy delivery from EN or PN alone which was higher in patients receiving VV-ECMO (91.3% (83.0–95.7%) *vs.* 85.7% (76.7–92.4%), $p = .003$) (Figs. 2 and 3). Overall, 193 (76.6%) patients received both adequate energy and protein over the course of their ICU admission.

Overfeeding occurred in less than 10% of patients when accounting for all energy sources (18 (7.1%)) or from EN and PN alone (2 (.8%)). However, underfeeding protein occurred in more than 20% of patients overall (55 (21.8%)). Similar rates of feeding adequacy were seen between those who received VV-ECMO and those who did not (Table 2). However, the days taken to reach adequate energy (2.0 days (2.0–3.0 days) *vs.* 2.0 days (2.0–3.0 days), $p = .006$), adequate protein (2.0 days (2.0–3.0 days) *vs.* 3.0 days (2.0–4.5 days), $p = .003$) and both adequate energy and protein (2.0 days (2.0–3.0 days) *vs.* 3.0 days (2.0–4.5 days), $p = .006$) were longer in patients receiving VV-ECMO.

Proning did not affect the overall percentage of energy targets met. Patients who were proned on at least one occasion received more overall energy (98.3% (92.2–104.9) *vs.* 95.6% (85.6–101.0%), $p = .002$) and protein (95.9% (84.9–102.4%) *vs.* 90.2% (90.8–98.7%), $p = .022$) targets than patients who were not proned.

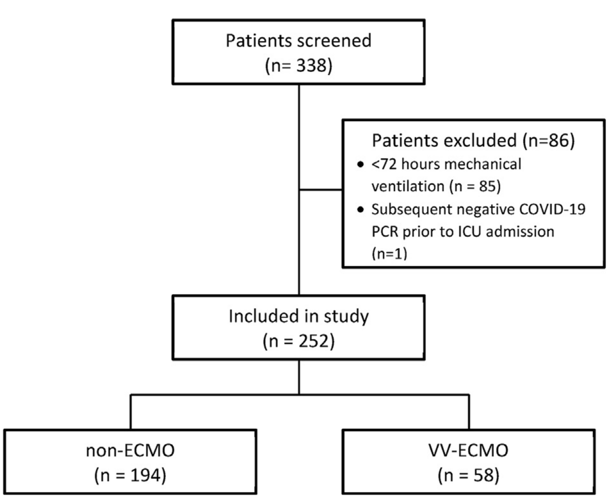

Fig. 1. Study flowchart.
Figure shows screening and inclusion/exclusion of participants
Abbreviations: COVID-19 = Coronavirus disease 2019; VV-ECMO = venovenous extracorporeal membrane oxygenation.

3.2. Enteral feeding intolerance and interruptions

High gastric residual volumes were recorded in 117 (46.6%) patients with a higher proportion of patients receiving VV-ECMO experiencing this compared with patients not receiving VV-ECMO (37 (63.8%) *vs.* 80 (41.5%), $p = .03$) (Table 3). More than 50% of patients received prokinetics at some point over the course of their ICU admission with a significantly higher proportion being received in patients requiring VV-ECMO compared with non-VV-ECMO patients (43 (74.1%) *vs.* 93 (47.9%), $p = .000$).

Data relating to feeding interruptions were collected for the 59 (n = 14 VV-ECMO) patients who received <80% of their energy or protein targets with almost all these patients having at least one feeding interruption recorded (57 (96.9%)) with a cumulative median (IQR) total of 35.0 h (15.5–65.0 h) per patient. Planned extubation was the main reason for feeding interruptions and accounted for just over 25% of episodes (Table 3).

3.3. Post-ICU nutrition management (ward)

A total of 111 patients stepped down to a local hospital ward, with 107 (96.4%) receiving ongoing dietetic input on step down (Table 4). No comparisons between patients receiving and not receiving VV-ECMO were made for any post-ICU nutrition management data due to the small number of VV-ECMO survivors stepping down to a local ward. A median (IQR) of 3 (2.0–5.0) dietetic contacts were recorded in the post-ICU hospital period. Ongoing NG feeding was required in 78 (70.3%) of patients for a median (IQR) of 3 days (1.0–6.0 days). The most common nutrition intervention on step-down to the ward was enteral plus oral nutrition support (60 (54.5%)) followed by oral nutrition support alone (44 (40%)). A texture modified diet was required in 45.9% (n = 51) of patients and more than 20% of patients (24 (21.6%)) were deemed to be unsafe for any solid food on step-down from ICU. Nearly 15% of patients (n = 16 (14.4%)) were unsafe for oral fluids and 25.2% (n = 28) required modified consistency fluids or were allowed sips of fluid only (Table 4).

3.4. Post-ICU nutrition management (hospital discharge)

A total of 62 (43.7%) patients were referred to the dietitian from the post-recovery follow-up clinic (Table 5). The median time to clinic appointment was 41.0 days (30.0–59.0 days) following hospital discharge. The most common reason for referral was significant weight loss (25 (20.8%)). Patients reported a vast number of symptoms at the post-ICU recovery clinic that could either impact on nutritional intake and nutrition status or could be a result of poor nutritional intake and nutrition status (Table 5). The most commonly reported symptoms were taste changes (40 (71.8%)) followed by breathlessness (101 (71.1)) and fatigue (97 (68.3)). All other symptoms can be seen in Table 5.

Table 1
Baseline characteristics.

Variable	All (N = 252)	Non-ECMO (n = 194)	VV-ECMO (n = 58)	*p* value
Age	53.5 (12.5)	56.0 (12.5)	45.0 (8.5)	.000
Sex (male), No. (%)	184 (73.0)	141 (72.7)	43 (74.1)	.868
Ethnicity				–
White	92 (36.5)	67 (34.5)	25 (43.1)	
Mixed	3 (1.2)	2 (1.5)	0 (.0)	
Asian	17 (6.7)	13 (6.7)	4 (6.9)	
Black	63 (25.0)	57 (29.4)	6 (10.3)	
Other	29 (11.5)	14 (7.2)	15 (25.9)	
Unknown	48 (19.0)	40 (20.6)	8 (13.8)	
BMI (kg/m^2)	29.3 (26.0–34.6)	29.1 (25.7–34.8)	31.3 (27.5–34.2)	.260
Underweight (<18.5)	1 (.4)	1 (.5)	0 (.0)	
Normal (18.5–24.9)	40 (15.9)	35 (18.0)	5 (8.6)	
Overweight (25–29.9)	101 (40.1)	74 (38.1)	27 (46.6)	
Obese I (30–34.9)	52 (20.6)	39 (20.1)	13 (22.4)	
Obese II (35–39.9)	41 (16.3)	33 (17.0)	8 (13.8)	
Obese III (≥40)	17 (6.7)	12 (6.2)	5 (8.6)	
APACHE II	14.6 (4.8)	14.6 (4.9)	14.7 (4.3)	.832
SOFA	6.0 (2.5)	5.9 (2.5)[b]	6.6 (2.8)	.087
Co-morbidities				
Hypertension	113 (44.8)	101 (52.1)	12 (20.7)	.000
Diabetes	92 (36.5)	81 (41.7)	9 (15.5)	.000[a]
Respiratory	50 (19.8)	40 (20.6)	10 (17.2)	.745
Immunocompromised	25 (9.9)	22 (11.3)	1 (1.7)	.103
Cardiac	20 (7.9)	17 (8.7)	3 (5.2)	.960
Sedation received, No. (%)	252 (100.0)	194 (100)	58 (100.0)	–
Sedation days	14.0 (9.0–22.0)	13.0 (8.0–21.0)	18.0 (11.8–25.5)	.011
Neuromuscular blockade agent received, No. (%)	184 (73.0)	130 (67.0)	54 (93.1)	.000
Neuromuscular blockade agent days	4.0 (2.0–8.0)	4.0 (2.0–8.0)	4.0 (2.0–7.0)	.004
Vasopressors received, No. (%)	212 (84.1)	165 (85.1)	47 (81.0)	.463
Vasopressor days	6.0 (3.0–9.0)	7.0 (3.0–11.0)	4.0 (2.0–6.0)	.001
RRT received, n (%)	104 (41.3)	81 (41.8)	23 (39.7)	.776
RRT days	11.0 (6.0–18.0)	11.0 (6.0–7.5)	13.0 (9.0–18.0)	.998
Proning, No. (%)	95 (37.7)	87 (44.8)	8 (13.8)	.000
Proning occasions	3.0 (2.0–5.0)	3.0 (2.0–5.0)	1.5 (1.0–3.5)	.000
Pre-ICU LOS	1.0 (.0–3.0)	1.0[c] (.0–2.0)	2.0 (.0–4.0)	.007
Received VV-ECMO, n (%)	58 (23.0)	0 (.0)	58 (100.0)	–
Duration of VV-ECMO	n/a	n/a	14.5 (9.0–22.0)	–
Duration of Mechanical ventilation	16.0 (10.0–26.0)	15.0 (9.0–26.0)	18.5 (11.0–26.3)	.199
Length of ICU stay	18.0 (11.0–31.0)	17.5 (10.0–31.0)	20.5 (13.0–27.3)	.422
Post-ICU length of stay	16.0 (6.0–24.0)	14.0[d] (6.0–23.0)	27.0 (19.5–28.5)	.063
Length of hospital stay*	31.0 (15.0–54.0)	27.0[e] (14.3–49.0)	52.0 (27.0–65.0)	.000
Survival, No. (%)	172 (68.3)	129 (66.5)	43 (74.1)	.273
Transferred into GSTT ICU, n (%)	107 (42.5)	50 (25.8)	57 (98.3)	.000
Destination post-ICU				
Local ward	111 (44.0)	106 (54.6)	5 (8.6)	.000
Other hospital	62 (24.6)	24 (12.4)	38 (65.5)	

Missing data for some variables as follows: [b]n = 191; [c]n = 193; [d]n = 95; [e]n = 184; [f]n = 105.
Abbreviations: APACHE II = Acute Physiology and Chronic Health Evaluation II; BMI = body mass index; ICU = intensive care unit; SOFA = sequential organ failure assessment; VV-ECMO = venovenous extracorporeal membrane oxygenation.
[a] Fishers exact.

4. Discussion

There are a number of important findings from this study. First, neither VV-ECMO nor proning were barriers to adequate nutrition provision in critically ill COVID-19 patients, however planned extubation was a frequent reason for enteral feed interruptions. The majority of patients were either nil by mouth or prescribed texture-modified diets at the time of stepdown from critical care to the ward and 70% of patients still had a nasogastric tube insitu at this time. High rates of nutrition related symptoms persisted following hospital discharge though this was not reflected in reports of weight-loss. Focussing attention and resources to challenges identified in this study may help to improve nutritional care and services to critically ill patients with COVID-19 throughout their trajectory of care.

To our knowledge, this is the largest dataset describing nutrition adequacy and nutrition related issues in critically ill COVID-19 positive patients which compares a cohort receiving VV-ECMO to a non-ECMO cohort. This is also the most comprehensive observational study to follow these patients through their trajectory of care, mapping nutritional issues up until a post-ICU clinic appointment when patients were back in the community.

4.1. Route of feeding, time to feeding and adequacy of nutrition support

The use of PN in this cohort was low with less than 5% of patients receiving PN during their ICU admission. This is in contrast to several others who have reported PN use of 16–51% in COVID-19 positive cohorts [11,14]. This may be related to higher supplemental PN usage in these other studies which may reflect differences in local practices, or more conservative thresholds for GI intolerance. Our results are more similar to those published by Terblanche and colleagues [13], whose population and local practices appear closer to our own given both centres are London-based

Table 2
Feeding and Nutrition data.

	All	Non-ECMO	VV-ECMO	*p* value
Energy target (kcal)	1916.7 (263.8)	191,971 (277.9)	1906.5 (212.0)	.739
Protein target (g)	101.3 (72.0)	101.7 (81.5)	99.8 (17.4)	.854
Percent energy received	96.4 (88.5–101.6)	96.2 (88.5–101.5)	96.9 (87.7–102.4)	.968
Percent energy received from EN/PN	87.1 (77.9–93.4)	85.7 (76.7–92.4)	91.3 (83.0–95.7)	.003
Percent protein received	92.2 (81.4–100.5)	91.6 (81.2–100.2)	94.4 (82.6–101.5)	.483
Energy adequacy Total, No. (%)				.617
Underfeeding	28 (11.1)	20 (10.3)	8 (13.8)	
Adequate feeding	206 (81.7)	161 (83.0)	45 (77.6)	
Overfeeding	18 (7.1)	13 (6.7)	5 (8.6)	
Energy adequacy feed only, No. (%)				.090
Underfeeding	76 (30.2)	65 (33.5)	11 (19.0)	
Adequate feeding	174 (69.0)	127 (65.5)	47 (81.0)	
Overfeeding	2 (0.8)	2 (1.0)	0 (0.0)	
Protein adequacy, No. (%)				.729
Underfeeding	55 (21.8)	43 (22.2)	12 (20.7)	
Adequate feeding	188 (74.6)	145 (74.7)	43 (74.1)	
Overfeeding	9 (3.6)	6 (3.1)	3 (5.2)	
Energy and protein adequacy	193 (76.6)	149 (76.8)	44 (75.9)	.882
Time to feeding (hours)	9.6 (6.5–14.0)	9.0 (6.0–13.4)	10.4 (8.0–15.0)	.057
Days to reach adequate energy[a]	2.0 (2.0–3.0)[a]	2.0 (2.0–2.0)[c]	2.0 (2.0–3.0)[e]	.006
Days to reach adequate protein[b]	2.0 (2.0–3.0)[b]	2.0 (2.0–3.0)[d]	3.0 (2.0–4.5)[e]	.003
Days to reach adequate energy and protein[b]	2.0 (2.0–3.0)[b]	2.0 (2.0–3.0)[d]	3.0 (2.0–4.5)[e]	.006
Time to dietetic review	48.0 (37.0–68.0)	48.0 (33.4–68.0)	47.7 (39.1–68.0)	.681
Feeding route				
Nasogastric	251 (99.6)	193 (99.5)	58 (100.0)	1.000
Post-pyloric	14 (5.6)	4 (2.1)	10 (17.2)	.000
Parenteral nutrition	12 (4.8)	9 (4.6)	3 (5.2)	1.000
Feeding type				
Low volume	115 (45.8)	86 (44.6)	29 (50.0)	.548
Additional water[f]	67 (59.3)	47 (56.0)	20 (69.0)	

Missing data for some variables as follows.
[a] n = 249, 3 patients never received adequate energy.
[b] n = 248, 3 patients never reached adequate protein or adequate energy and protein.
[c] n = 192, 2 patients never reached adequate energy.
[d] n-192, 3 patients never reached adequate protein or adequate energy and protein.
[e] n = 57, 1 patient never reached adequate protein, adequate energy or adequate energy and protein.
[f] n = 29, only for those patients receiving low volume feed; Abbreviations: kcal = kilocalories, g = grams, EN = enteral nutrition, PN = parenteral nutrition.

NHS tertiary referral hospitals with large pre-existing ICUs prior to the COVID-19 pandemic.

The finding of better energy adequacy with enteral feed in the VV-ECMO compared to non-ECMO cohort is surprising given previous studies suggest that patients receiving ECMO are relatively poorly fed with significant enteral feeding interruptions [19,20]. This may be explained by the difference in the use of propofol between the patient cohorts and the preferential use of 2% propofol for the VV-ECMO cohort during times of propofol shortage. Given these excess calories were being taken into account by the ICU dietitians when devising feeding regimens to prevent overfeeding explains, in part, the higher energy adequacy when looking at enteral feed only. Of note Castro and colleagues [21] report higher rates of enteral feed delivery in a VV-ECMO vs non-ECMO cohort. The potential reasons behind this are not discussed, however indicates that there may be another more general root cause for this, such as VV-ECMO patients receiving more intensive dietetic or nursing input to rectify feeding issues in a more timely manner.

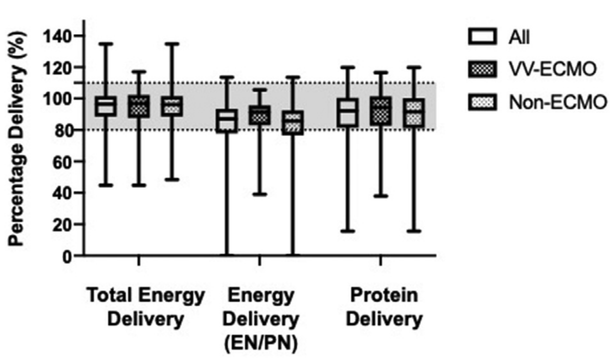

Fig. 2. Figure of energy and protein delivery.
Figure shows the percentage delivery of total energy (including all sources), energy delivery from EN and PN alone and the protein delivery for the total group, VV-ECMO and non VV-ECMO patients. Box plot indicates median values with interquartile range. Whiskers indicate minimum and maximum values. Shaded area indicates adequacy level (80–110% targets). $p = .003$ for the difference between energy delivery (EN/PN) between those who received VV-ECMO and those who did not, otherwise no statistical significance between groups.
Abbreviations: EN = enteral nutrition; PN = parenteral nutrition; VV-ECMO = venovenous extracorporeal membrane oxygenation.

Another unexpected finding of this study was that patients who were proned received both more energy and protein compared to those who were not proned. Whilst Savio and colleagues [27] reported similar amounts of energy provision in proned vs supine patients with severe acute respiratory distress syndrome, the proned patients received lower protein provision [27]. The increased energy received in this study may again be related to higher propofol usage in proned patients, who may require deep sedation during turning and proning [28]. The higher protein adequacy however can only come from improved feed and/or modular protein supplement provision. One potential explanation could be that patients who were proned may have had longer critical care length of stays, thereby allowing for more enteral feed to be delivered over time. Regardless of the reason behind this

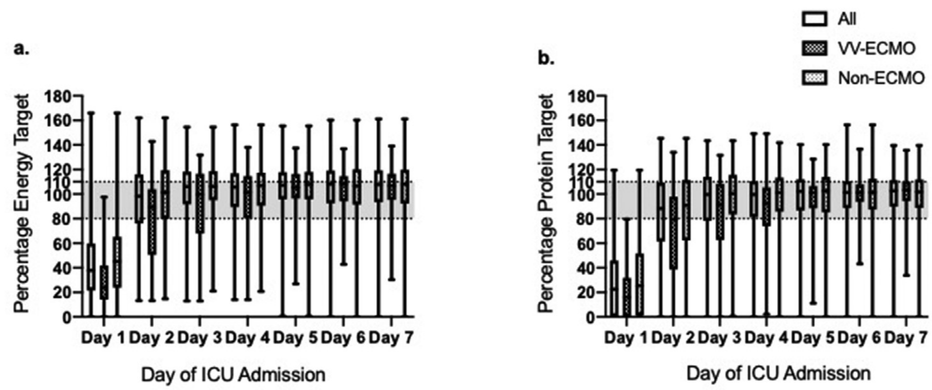

Fig. 3. Figure of daily energy and protein delivery for the first 7 days.
Figure shows the daily percentage delivery of total energy (including all sources), and protein delivery for the first 7 days of ICU admission. Box plot indicates median values with interquartile range. Whiskers indicate minimum and maximum values. Shaded area indicates adequacy level (80–110% targets).
Abbreviations: ICU = intensive care unit; VV-ECMO = venovenous extracorporeal membrane oxygenation.

result, this study provides evidence that proning should not be a barrier to enteral feeding and good nutritional adequacy in critically ill patients.

4.2. Enteral feeding intolerance and interruptions

This study reports high GRVs in almost half of the patient cohort, which is in contrast to others [16] who found only on quarter of COVID-19 patients experienced high GRVs. Interestingly, their GRV threshold was also set at 300 ml, and both the APACHE II and SOFA scores are higher, therefore this difference is unlikely to be related to severity of illness. Their study does however only run for the 1st 7 days, and it is unclear how frequently GRVs were measured during the study period. It may be that rates of high GRVs increase as the critical care stay progresses, or that in our population GRVs could have been recorded more frequently, thereby capturing a higher number of instances. Remarkably, the patients in the Osuna-padilla et al. study received enteral feeding over an 18-h period [16], as opposed to over 24 h in this study. Given cyclic feeding is thought to increase the rate of feeding intolerance and GRVs [29], this again suggests some other difference between these to study groups which lead to a two-fold difference in high aspirates. The prevalence of high GRVs reported in this study are similar to those reported by Liu and colleagues [15], though the definition of a high GRV was significantly different, as in their study a volume threshold was not used, but instead any aspirate which led to enteral nutrition being withheld was considered high. Despite high levels of GRVs, high use of prokinetics and possibly, high levels of dietetic input likely prevented this from resulting in poor nutritional adequacy.

The finding of planned extubation as the main reason behind feeding interruptions may be related to the severity of respiratory failure in COVID-19 patients, and the uncertainty around the management of these patients early in the course of the pandemic. This likely led to high rates of anticipated extubation which either failed or were then found to be inappropriate and not attempted. This is in line with a survey-study by Suliman and colleagues [30] whereby respondents indicated that 'unclear clinical course' was one of the main barriers to the delivery of enteral nutrition.

4.3. Post-ICU nutrition management (ward)

In this cohort of patients, 7 in 10 patients had an NG tube insitu at the time of ward stepdown. This is similar to the numbers reported by Terblanche et al. [13] and slightly higher than the 6 in 10 patients reported by Weirdsma and colleagues [24]. This is indicative not only of ongoing nutritional issues, but of a service-wide

Table 3
Feeding intolerance and interruptions.

	ALL	Non-ECMO	VV-ECMO	*p* value
High GRVs, No. (%)	117 (46.6)	80 (41.5)	37 (63.8)	.03
Prokinetics	136 (54.0)	93 (47.9)	43 (74.1)	.000
Feed stoppages[a], No. (%)	57 (96.9)	44 (97.8)	13 (92.9)	.374
Number of feed stoppages[a]	4.0 (2.5–6.5)	4.0 (2.0–6.0)	4.5 (2.75–8.0)	.476
Total hours of feed stoppages	35.0 (15.5–65.0)	36.0 (17.25–60.75)	24.5 (6.25–72.5)	.277
Reasons for feed stoppages				
Planned extubation	15 (26.3)	14 (31.8)	1 (7.7)	n/a
Other	11 (19.3)	9 (20.5)	2 (15.4)	
Tube dislodgement	9 (15.8)	7 (15.9)	2 (15.4)	
Vomiting	7 (12.3)	4 (9.1)	3 (23.1)	
Unclear	4 (7.0)	2 (4.5)	2 (15.4)	
High GRV	3 (5.3)	2 (4.5)	1 (7.7)	
Procedures	3 (5.3)	1 (2.3)	2 (15.4)	
Proning	3 (5.3)	3 (6.8)	0 (.0)	
Tracheostomy	1 (1.8)	1 (2.3)	0 (.0)	
Tube blockage	1 (1.8)	1 (2.3)	0 (.0)	

Abbreviations: GRVs = gastric residual volumes; VV-ECMO = venovenous extracorporeal membrane oxygenation.
[a] All n = 59, VV-ECMO n = 14, only included patients who did not meet more than 80% of energy or protein targets.

Table 4
Post-ICU nutrition management (ward).

	ALL (n = 111)
Reviewed by ward dietitian	107 (96.4)
Number of dietetic contacts	3 (2.0–5.0)
NGT in situ on step-down	77 (70.0)
Enteral feeding days	3 (1.0–6.0)
Ward interventions	
ONS alone	44 (40.4)
ENS alone	2 (1.8)
ONS and ENS	59 (54.1)
PNS and ENS	1 (0.9)
PNS, ENS and ONS	1 (.9)
Other	2 (1.8)
Diet at time of ward step-down	
Normal	36 (32.4)
Level 6 Soft and bite-sized	18 (16.4)
Level 5 minced	5 (4.5)
Level 4 puree	13 (11.8)
Custard/yoghurt only	14 (12.7)
No solids	24 (21.8)
Fluid at time of ward step-down	
Thin	66 (60.0)
Thickened fluids	3 (2.7)
Sips only	25 (22.7)
Nil	16 (14.5)

Abbreviations: ICU = intensive care unit; ENS = enteral nutrition support; NGT = nasogastric tube; ONS = oral nutrition support; PNS = parenteral nutrition support; VV-ECMO = venovenous extracorporeal membrane oxygenation.

Table 5
Post-ICU nutrition management (hospital discharge).

	ALL
Referral to dietetic clinic post-hospital discharge	49 (28.4)
Dietetic referral reason	
Significant weight loss	21 (42.9)
Poor appetite	11 (22.4)
Weight gain	8 (16.3)
PG-SGA score	2 (4.1)
Offered, but declined	1 (2.0)
Other	6 (12.2)
Days from hospital discharge to Post-ICU clinic appointment	41.0 (30.0–59.0)
Symptoms[a]	
Breathlessness	101 (71.1)
Fatigue	97 (68.3)
Muscle weakness	77 (54.2)
Hair loss	43 (30.3)
Taste changes	40 (28.2)
Poor appetite	20 (14.1)
Change in bowel habit	18 (12.7)
Dysphagia	17 (12.0)
Weight loss	11 (7.8)

Abbreviations: PG-SGA = patient generated subjective global assessment.
[a] Symptoms as reported in post-ICU recovery clinic (n = 142).

understanding of the importance of nutrition to the rehabilitation of these patients. More than half of the patients who stepped down to the ward were receiving both enteral and oral nutrition support, which suggests an understanding by staff that in the post-ICU period there are many barriers to eating [31,32] and patients may struggle to meet their nutritional needs with food and oral nutrition support alone [33].

Texture modified diets and 'nil by mouth' status at the time of ward step down was recorded in two thirds of patients at the time of ICU discharge. This is similar to texture modified diet rates reported by Weirdsma and colleagues [24], as well as post-extubation dysphagia rates reported by Hoiyoes et al. [12], which is the presumed issue underlying these dietary restrictions.

4.4. Post-ICU nutrition management (hospital discharge)

In-line with other literature [24], there were high rates of nutrition related symptoms even several months following hospital discharge. Despite these high rates of symptoms that are likely to impact nutritional intake (such as breathlessness, fatigue, taste changes, poor appetite, and dysphagia) loss of weight was recorded as an issue in less than 1 in 10 patients. This could indicate that patients had successfully implemented strategies to maximise caloric intake despite these challenges, or alternatively it may indicate that weight-loss was a symptom that was less enquired about by clinicians in the post-ICU clinic, particularly given clinics were taking place virtually as opposed to in-person where patients can be weighed at the clinic appointment. Further research into the actual weight-loss of this patient group following discharge to the community, as well as clinicians' attitudes regarding the importance of unintentional weight loss in a post-ICU clinic setting is warranted.

4.5. Strengths and limitations

There are several strengths to this study. Data were collected on relatively large patient numbers, data collection continued for the entire ICU admission and the full patient journey onto the ward and following discharge were considered. With the significantly increased patients admitted to our critical care service, the core critical care dietitians were supplemented with a large number of surge dietitians with limited prior critical care experience, who were provided with training and clinical supervision to ensure that standards of nutritional care were upheld as much as possible.

As with all retrospective studies examining medical records, data collected is based on what has been recorded, and will not always accurately reflect all the relevant information. However, as the authors were clinically involved with the patients during the timeframe when data was examined, we can attest that, overall, the data reflects what was occurring on a gross scale. Data regarding weights at ICU admission are largely based on visual estimates due to the difficulties in acquiring actual weight in critically ill patients. Furthermore, whilst we attempted to collect data regarding weight changes throughout hospitalisation and at post-ICU clinic, there was sparse information available and there was some conflicting data, as patient reported information and supposed recorded weights were often very different. As such this data was excluded from analysis. The data collected for VV-ECMO patients in the post ICU hospitalisation period was very limited due to the high numbers of patients repatriated to local centres following ECMO decannulation.

5. Conclusion

Despite the pressures of the COVID-19 pandemic on intensive care services, it was possible to ensure a significant number of patients reached nutritional adequacy by utilising the increased dietetic capacity. Neither VV-ECMO nor proning were barriers to nutritional adequacy in this critically ill COVID-19 cohort. Nutritional issues for patients who were critically unwell with COVID-19 persist following stepdown to ward level and into the community for some of these patients, but the impact of this on nutritional status requires further exploration.

Funding statement

This work was supported by a grant from Nutricia Ltd.

Author contributions

Georgia Hardy: Conceptualisation, data curation, funding acquisition, methodology, investigation, writing - original draft.

Luigi Camporota: formal analysis, writing – review & editing.

Danielle Bear: Conceptualisation, data curation, formal analysis, funding acquisition, methodology, writing - review & editing.

Conflict of interest

GH received conference registration fees from Nutricia Ltd. LC has no conflicts of interest to declare. DEB has received speaker fees from Baxter Healthcare.

Acknowledgments

We would like to thank all the dietitians and dietitian assistants who helped to care for these patients, and collected some of the nutritional adequacy data as part of clinical care: Emma Armstrong, Annika Coombes, Rachel Davis, Narbhla Donnelly, Lucy Garnier, Tarryn Guttenberg, Tomos Hollis, Emma Jarvis, Alice Kershaw, Natasha Mir, Amanda Owers, Angela Reddy, Sophie Rodd, Liesl Wandrag.

We would also like to thank Dr Andrew Jones, Alison Dixon and Angelo Sousa from the critical care audit team for assistance with high level data acquisition.

References

[1] Arabi YM, Azoulay E, Al-Dorzi HM, Phua J, Salluh J, Binnie A, et al. How the COVID-19 pandemic will change the future of critical care. Intensive Care Med 2021;47:282–91. https://doi.org/10.1007/s00134-021-06352-y.

[2] Bear D, Terblanche E. Critical Care Specialist Group (CCSG) of the BDA Guidance on management of nutrition and dietetic services during the COVID-19 pandemic. British Dietetic Association; 2020. https://www.bda.uk.com/resource/critical-care-dietetics-guidance-covid-19.html. [Accessed 17 October 2021].

[3] Barazzoni R, Bischoff SC, Breda J, Wickramasinghe K, Krznaric Z, Nitzan D, et al. ESPEN expert statements and practical guidance for nutritional management of individuals with SARS-CoV-2 infection. Clin Nutr 2020;39:1631–8. https://doi.org/10.1016/j.clnu.2020.03.022.

[4] Martindale R, Patel JJ, Taylor B, Warren M, Mcclave SA. Nutrition therapy in the patient with COVID-19 disease requiring ICU care. J Parenter Enteral Nutr 2020;44:1174–84.

[5] Chapple L, Fetterplace K, Asrani V, Burrell A, Cheng AC, Collins P, et al. Nutrition management for critically and acutely unwell hospitalised patients with coronavirus disease 2019 (COVID-19) in Australia and New Zealand. Nutr Diet 2020;77:426–36. https://doi.org/10.1111/1747-0080.12636.

[6] Rives-Lange C, Zimmer A, Merazka A, Carette C, Martins-Bexinga A, Hauw-Berlemont C, et al. Evolution of the nutritional status of COVID-19 critically-ill patients: a prospective observational study from ICU admission to three months after ICU discharge. Clin Nutr 2021. https://doi.org/10.1016/j.clnu.2021.05.007.

[7] Shahbazi S, Hajimohammadebrahim-Ketabforoush M, Vahdat Shariatpanahi M, Shahbazi E, Vahdat Shariatpanahi Z. The validity of the global leadership initiative on malnutrition criteria for diagnosing malnutrition in critically ill patients with COVID-19: a prospective cohort study. Clin Nutr ESPEN 2021;43:377–82. https://doi.org/10.1016/j.clnesp.2021.03.020.

[8] Yu PJ, Cassiere H, DeRosa S, Bocchieri K, Yar S, Hartman A. Hypermetabolism and coronavirus disease 2019. J Parenter Enteral Nutr 2020;44:1234–6. https://doi.org/10.1002/jpen.1948.

[9] Whittle J, Molinger J, MacLeod D, Haines K, Wischmeyer PE. Persistent hypermetabolism and longitudinal energy expenditure in critically ill patients with COVID-19. Crit Care 2020;24. https://doi.org/10.1186/s13054-020-03286-7.

[10] Lakenman PLM, van der Hoven B, Schuijs JM, Eveleens RD, van Bommel J, Olieman JF, et al. Energy expenditure and feeding practices and tolerance during the acute and late phase of critically ill COVID-19 patients. Clin Nutr ESPEN 2021;43:383–9. https://doi.org/10.1016/j.clnesp.2021.03.019.

[11] Cuerda C, Sánchez López I, Gil Martínez C, Merino Viveros M, Velasco C, Cevallos Peñafiel V, et al. Impact of COVID-19 in nutritional and functional status of survivors admitted in intensive care units during the first outbreak. Preliminary results of the NUTRICOVID study. Clin Nutr 2021. https://doi.org/10.1016/j.clnu.2021.11.017.

[12] Hoyois A, Ballarin A, Thomas J, Lheureux O, Preiser JC, Coppens E, et al. Nutrition evaluation and management of critically ill patients with COVID-19 during post–intensive care rehabilitation. J Parenter Enteral Nutr 2021;45: 1153–63. https://doi.org/10.1002/jpen.2101.

[13] Terblanche E, Hills J, Russell E, Lewis R, Rose L. Dietetic-led nutrition interventions in patients with COVID-19 during intensive care and ward-based rehabilitation: a single-center observational study. Nutrients 2022;14. https://doi.org/10.3390/nu14051062.

[14] Cereda E, Guzzardella A, Klersy C, Belliato M, Pellegrini A, Sciutti F, et al. Early caloric deficit is associated with a higher risk of death in invasive ventilated COVID-19 patients. Clin Nutr 2021. https://doi.org/10.1016/j.clnu.2021.02.020.

[15] Liu R, Paz M, Siraj L, Boyd T, Salamone S, Lite TLV, et al. Feeding intolerance in critically ill patients with COVID-19. Clin Nutr 2021. https://doi.org/10.1016/j.clnu.2021.03.033.

[16] Osuna-Padilla I, Rodríguez-Moguel NC, Aguilar-Vargas A, Rodríguez-Llamazares S. Safety and tolerance of enteral nutrition in COVID-19 critically ill patients, a retrospective study. Clinical Nutrition ESPEN 2021;43:495–500. https://doi.org/10.1016/j.clnesp.2021.02.015.

[17] Extracorporeal Life Support Organization. Extracorporeal Membrane Oxygenation (ECMO) in COVID-19 n.d. https://www.elso.org/COVID19.aspx (accessed March 23, 2022).

[18] Davis RC, Durham LA, Kiraly L, Patel JJ. Safety, tolerability, and outcomes of enteral nutrition in extracorporeal membrane oxygenation. Nutr Clin Pract 2021;36:98–104. https://doi.org/10.1002/ncp.10591.

[19] MacGowan L, Smith E, Elliott-Hammond C, Sanderson B, Ong D, Daly K, et al. Adequacy of nutrition support during extracorporeal membrane oxygenation. Clin Nutr 2019;38:324–31. https://doi.org/10.1016/j.clnu.2018.01.012.

[20] Lukas G, Davies AR, Hilton AK, Pellegrino VA, Scheinkestel CD, Ridley E. Critical care and resuscitation. Crit Care Resuscit 2010;12:230–4.

[21] Castro M, Diament D, Nogueira P, Pfeilsticker F, Toledo D, Laselva C. P163 Tolerability of enteral nutrition in extracorporeal membrane oxygenation and COVID-19. Clin Nutr ESPEN 2021;46:641.

[22] Ridley EJ, Chapple LAS, Chapman MJ. Nutrition intake in the post-ICU hospitalization period. Curr Opin Clin Nutr Metab Care 2020;23:111–5. https://doi.org/10.1097/MCO.0000000000000637.

[23] Geers J, Demol J, Verhelst C, Jonckheer J, de Waele E. P157 Adequacy of nutritional therapy of covid-19 patients during their ICU and ward stay: better is worse. Clin Nutr ESPEN 2021;46:639.

[24] Wierdsma NJ, Kruizenga HM, Konings LA, Krebbers D, Jorissen JR, Joosten MHI, et al. Poor nutritional status, risk of sarcopenia and nutrition related complaints are prevalent in COVID-19 patients during and after hospital admission. Clin Nutr ESPEN 2021;43:369–76. https://doi.org/10.1016/j.clnesp.2021.03.021.

[25] Warren A, Chiu Y-D, Villar SS, Fowles J, Symes N, Barker J, et al. Outcomes of the NHS England National Extracorporeal Membrane Oxygenation Service for adults with respiratory failure: a multicentre observational cohort study. Br J Anaesth 2020;125:259–66. https://doi.org/10.1016/j.bja.2020.05.065.

[26] Frankenfield D, Smith JS, Cooney RN. Validation of 2 approaches to predicting resting metabolic rate in critically ill patients. J Parenter Enteral Nutr 2004;28: 259–64. https://doi.org/10.1177/0148607104028004259.

[27] Savio RD, Parasuraman R, Lovesly D, Shankar B, Ranganathan L, Ramakrishnan N, et al. Feasibility, tolerance and effectiveness of enteral feeding in critically ill patients in prone position. J Intensive Care Soc 2021;22: 41–6. https://doi.org/10.1177/1751143719900100.

[28] Chanques G, Constantin JM, Devlin JW, Ely EW, Fraser GL, Gélinas C, et al. Analgesia and sedation in patients with ARDS. Intensive Care Med 2020;46: 2342–56. https://doi.org/10.1007/s00134-020-06307-9.

[29] Ma Y, Cheng J, Liu L, Chen K, Fang Y, Wang G, et al. Intermittent versus continuous enteral nutrition on feeding intolerance in critically ill adults: a meta-analysis of randomized controlled trials. Int J Nurs Stud 2021;113: 103783. https://doi.org/10.1016/j.ijnurstu.2020.103783.

[30] Suliman S, McClave SA, Taylor BE, Patel J, Omer E, Martindale RG. Barriers to nutrition therapy in the critically ill patient with COVID-19. J Parenter Enteral Nutr 2021. https://doi.org/10.1002/jpen.2263.

[31] Merriweather JL, Griffith DM, Walsh TS. Appetite during the recovery phase of critical illness: a cohort study. Eur J Clin Nutr 2018;72:986–92. https://doi.org/10.1038/s41430-018-0181-3.

[32] Merriweather JL, Salisbury LG, Walsh TS, Smith P. Nutritional care after critical illness: a qualitative study of patients' experiences. J Hum Nutr Diet 2016;29: 127–36. https://doi.org/10.1111/jhn.12287.

[33] Ridley EJ, Parke RL, Davies AR, Bailey M, Hodgson C, Deane AM, et al. What happens to nutrition intake in the post–intensive care unit hospitalization period? An observational cohort study in critically ill adults. J Parenter Enteral Nutr 2019;43:88–95. https://doi.org/10.1002/jpen.1196.