Clinical Nutrition 39 (2020) 3813–3820

Contents lists available at ScienceDirect

Clinical Nutrition

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

Original article

Nutritional therapy among burn injured patients in the critical care setting: An international multicenter observational study on "best achievable" practices

Michail Chourdakis [a, *], Emmanouil Bouras [a], Beth A. Shields [b], Christian Stoppe [c], Anne-Françoise Rousseau [d], Daren K. Heyland [e, f, **]

[a] School of Medicine, Faculty of Health Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece
[b] Department of Nutritional Medicine and Metabolism, Burn Unit, U.S. Army Institute of Surgical Research, Ft. Sam Houston, TX, USA
[c] Department of Intensive Care Medicine, University Hospital, RWTH Aachen, Germany
[d] Intensive Care Department and Burn Center, University Hospital, Liège, Belgium
[e] Department of Critical Care Medicine, Queen's University, Kingston, Ontario, Canada
[f] Clinical Evaluation Research Unit, Kingston General Hospital, Kingston, Ontario, Canada

ARTICLE INFO

Article history:
Received 29 January 2020
Accepted 10 April 2020

Keywords:
Mortality
ICU
Nutrition therapy
Micronutrients

SUMMARY

Background & aims: Burn patients pose a number of clinical challenges for doctors and dietitians to achieve optimal nutrition practice. The objective of this study was to describe nutrition practices in burn center intensive care units (ICUs) compared to the most recent ESPEN and SCCM/ASPEN guidelines (hereafter referenced as "the Guidelines") and highlight the variation in practice and what is "best achievable."

Methods: In 2014–15, we prospectively enrolled 283 mechanically ventilated patients who were admitted to one of 14 burn ICUs for at least 72 h. Data collected included information on the estimation of energy and protein requirements, their actual delivery as well as route and time of feeding, and administration of micronutrients. We describe site practices and data per patient-day.

Results: Adherence to the Guidelines for the use of enteral nutrition (EN) over parenteral nutrition (PN) was 90.5% of patient-days (site range 79.2%–97.0%). However, adherence to the Guidelines for the measurement of energy requirements was 6.0% of patient-days (site range 0.0%–93.3%), supplementation with glutamine took place in 22.4% of patient-days (site range 0.0%–61.8%). Provision of 80% of energy requirements within 48–72 h was achieved in 35.3% of patients (site range 0.0%–80.0%), and provision of 80% of protein needs within 48–72 h was achieved in 34.3% of patients (site range 0.0% –80.0%). Average nutritional adequacy was 64.9 ± 40.0% for energy (best site: 80.2%, worst site: 42.0%) and 65.6 ± 42.1% for protein (best site: 87.3%, worst site: 43.6%).

Conclusion: The present findings indicate that despite high adherence to providing EN over PN, there is still a large gap between many recommendations and clinical practice, and the achievement of nutrition goals for patients in burn centers is suboptimal.

1. Introduction

Patients with severe burns pose several nutritional challenges for both physicians and dietitians. Due to the perilous post-burn hypermetabolic response, increased losses and subsequent needs, and altered and dysregulated glucose metabolism [1–6], nutritional therapy is a critical component of severe burn treatment, as well as an important outcome effector [1]. The general framework of nutritional support is based on management of the hypercatabolic state, glycemic control, micronutrients supplementation, and of course adequate provision of energy and nutrients, with prompt feeding initiation via a tolerable and effective route [1–6].

Several professional organizations, including the European Society for Clinical Nutrition and Metabolism (ESPEN) and the Society

* Corresponding author. University Campus, Aristotle University of Thessaloniki, School of Medicine, Building 16A, Entrance 4, 54124, Thessaloniki, Greece.
** Corresponding author. Department of Critical Care Medicine, Queen's University, Kingston, Ontario, Canada.
E-mail addresses: mhourd@gapps.auth.gr (M. Chourdakis), dkh2@queensu.ca (D.K. Heyland).

https://doi.org/10.1016/j.clnu.2020.04.023
0261-5614/

of Critical Care Medicine (SCCM) with the American Society for Parenteral and Enteral Nutrition (ASPEN), have published recommendations for nutrition for critically ill burn patients [2,5], albeit given recommendations are based on low evidence levels (Supplementary Table 1). ESPEN and SCCM/ASPEN guidelines (hereafter referenced as "the Guidelines") agree in their recommendations for enteral nutrition (EN) be utilized for patients with a functional gastrointestinal tract and who are unable to meet nutrition goals with oral intake alone, reserving parenteral nutrition (PN) for those who are unable to tolerate or have a contraindication to EN; early initiation of EN (ESPEN: within 12 h from injury, SCCM/ASPEN: within 6 h from injury); the use of indirect calorimetry (IC) for the most accurate determination of energy goals; protein goals of 1.5–2.0 g/kg/d ("or higher" per SCCM/ASPEN); supplementation of vitamin C, zinc, and selenium; and glucose control (ESPEN: glucose levels between 81 and 144 mg/dL, SCCM/ASPEN: glucose levels between 140 or 150–180 mg/dL). ESPEN does not address the timing for achieving nutrition goals, but SCCM/ASPEN suggest that 80% of the energy and protein goals should be met within 48–72 h. ESPEN recommends glutamine supplementation; however, SCCM/ASPEN recommends against.

Evaluating compliance with nutrition guidelines is important from the point of view of obtaining optimal patient outcomes. Failure to translate this knowledge into practice may result in increased length of stay (LOS), but also morbidity and mortality for thousands of critically ill patients [7,8]. The present multicenter prospective study aimed to record nutritional strategies for patients admitted to burn center ICUs, and to examine adherence to the Guidelines. We compared actual practices among burn centers in an effort to define or establish the "best achievable" performance in key nutritional practices.

2. Methods

2.1. Study design and participants

Burn Intensive Care Units (ICUs) were recruited during the International Nutrition Survey (INS) in 2014 and 2015 for this prospective, observational study on nutrition practices. Patients were consecutively enrolled in the study when they met the following inclusion criteria: 1) age $\geq$18 years old, or $\geq$16 years old if approved locally at site, 2) on mechanical ventilation within 48 h of admission to the ICU, and 3) length of ICU stay $\geq$72 h from admission.

2.2. Data collection

For each patient included in the INS, sites collected data describing patient characteristics, ICU admission information, baseline nutrition assessment, daily nutrition data, and 60-day patient outcomes. As per our usual INS practices [7,9], and given the observational nature of this study, baseline nutrition assessment was not standardized across sites. Data on total calories and protein prescribed and received were recorded. For this, "*total calories and protein prescribed*" referred to the total as determined at the initial assessment, whereas "*total calories and protein received*" referred to the total received by EN or PN plus propofol, according to each center's standard protocol. Daily nutrition data, which included the initial feeding strategy and type and amount of nutrition received, were collected from ICU admission until ICU discharge or death, or for a maximum of 12 days. Oral intake was not included. Patient outcomes at day 60 were collected and included the date mechanical ventilation was discontinued, the dates of ICU and hospital discharge, and the date of death (if relevant). Data were abstracted from patient records and were entered online using a secure web-based data collection tool.

Body mass index (BMI) was calculated as body weight (kg) divided by the square of height (m^2). Upon admission, the Acute Physiology and Chronic Health Evaluation (APACHE) II [10] and the Sequential Organ Failure Assessment (SOFA) [11,12] scores were calculated, and the percent of total body surface area (%TBSA) burn was determined based on conventional surface estimation methods [13]. The abbreviated burn severity index (ABSI) [14], a five–item scale used to assess burn severity, was also calculated. The ABSI includes sex, age, presence of inhalation injury, presence of a full-thickness burn, and %TBSA. Nutritional risk was determined with the modified NUTrition Risk in the Critically ill (mNUTRIC) tool [15]. Glucose monitoring; insulin and feeding protocols were followed as usual in each center. Data management has been previously described [7].The research ethics committee at the lead site, Queens University, approved the INS. The need for informed consent was waived as this was an observational study, without interventions.

2.3. Statistical analyses

Categorical variables were described as counts and percentages, and continuous variables were reported as means with standard deviations and/or medians with interquartile range (IQR), depending on their distribution. Variables related to nutritional/clinical guidelines were reported as overall averages (or percentage of all patient-days across sites), along with the range of site averages (average result across all patients within an individual site). The site ranges are interpreted as the best and worst site performances relative to the nutritional/clinical guidelines. The calorie and protein intakes via the enteral or parenteral route were divided by the amount prescribed in the baseline assessment to determine percentage of the nutrition prescription achieved. Calories from propofol infusions (if > 6 h) were included in the calculation whereas calories from intravenous (IV) dextrose were not. Nutritional intake from oral nutrition was not included in the calculation of nutritional adequacy. Days after permanent progression to exclusive oral intake were excluded from the calculation of nutritional adequacy. We selected >80% nutritional adequacy as an indicator of high performance, based on previous publication from members of the group [16].

All analyses were performed using IBM SPSS Statistics version 23.0 (International Business Machines Corp., Armonk, New York, United States) and SAS® 9.4 (SAS® Institute Inc., Cary, North Carolina, USA), and the level of significance was set at $p < 0.05$.

3. Results

A total of 14 burn centers registered to participate in this survey, including 11 in the USA, one in Canada, one in South Africa, and one in Australia, enrolling 283 patients for 3085 total patient-days, with an average of 20.2 $\pm$ 6.7 patients per site (range: 15–41). Table 1 describes the ICU characteristics of the participating sites, and Table 2 shows the patient demographics. Table 3 summarizes the adherence of our sample to the Guidelines.

3.1. Feeding route

Guidelines recommend that EN be used in all critically ill patients with an intact gastrointestinal tract, and PN should not be used routinely. Figure 1 displays the percentage of patient-days where EN and PN were provided. EN was the predominated feeding route provided on 90.5% of the patient-days, ranging from 79.2% to 97.0% between worst and best sites, respectively. Oral feeding occurred during 18.2% of total patient-days, with 11.8% patient-days including oral supplement drinks. Neither EN nor PN

Table 1
Characteristics of participating centers.

		Total, n = 14
Geographic region	Australia	1 (7.1%)
	Canada	1 (7.1%)
	USA	11 (78.6%)
	South Africa	1 (7.1%)
Hospital type	Teaching	13 (92.9%)
	Non-teaching	1 (7.1%)
Size of hospital (beds) *Median (range)*		462.5 (280–1004)
ICU type	Closed	4 (28.6%)
	Open	7 (50.0%)
	Other	3 (21.4%)
Multiple ICUs in the hospital	Yes	13 (92.9%)
Medical Director	Yes	13 (92.9%)
Size of ICU (beds) *Median (range)*		12.5 (4–20)
Presence of dietitian(s)	Yes	14 (100%)
Full time equivalent dietitians (per 10 beds) *Median (range)*		0.5 (0.2–3.0)

ICU: Intensive Care Unit.

were provided for 9.5% of patient-days (site range: 3.0%–20.8% of patient-days), whereas there were no days with PN alone and PN + EN accumulated for less than 2% of patient-days.

3.2. EN initiation

The average time to EN initiation was 22.4 ± 20.1 h from ICU admission. The best performing site was able to initiate EN 4.9 ± 4.0 h after ICU admission; the worst site delayed initiation of EN for 47.5 ± 23.0 h, on average. EN was initiated within 6 and 12 h from admission in 18.7% and 35.0% of patients, respectively. The best site achieved EN initiation within 6 h from admission in 70.0% of patients, whereas the worst site had no success (0% of patients) in this. The best site achieved EN initiation within 12 from admission for 90.0% of patients, whereas the worst site had 5% success in this parameter. More information on the timing of initiation of EN can be found in Supplementary Table 2.

Table 2
Patient characteristics.

	Total, n = 283
Number of patients, per site *Mean (SD)*	20.2 (6.7)
Age, yrs *Mean (SD)*	46.6 (17.8)
Gender, Male/Female	190 (67.1%)/93 (32.9%)
BMI, kg/m^2 *Mean (SD)*	28.5 (7.8)
mNUTRIC score *Mean (SD)*	4.0 (1.6)
APACHE II score *Mean (SD)*	19.0 (8.1)
SOFA score *Mean (SD)*	15.0 (5.0)
TBSA, *% Mean (SD)*	30.0 (21.5)
ABSI *Mean (SD)*	7.5 (2.4)
Presence of ARDS	30 (10.6%)
Length of mechanical ventilation, days	
Mean (SD)	17.2 (18.1)
Median (IQR)	10.5 (3.9, 24.0)
Length of ICU stay, days	
Mean (SD)	28.9 (20.7)
Median (IQR)	22.7 (11.2, 48.2)
Length of hospital stay, days	
Mean (SD)	35.4 (20.2)
Median (IQR)	30.9 (16.4, 61.0)
Number of Patient died within 60 days	54 (19.1%)

ABSI: Abbreviated Burn Severity Index; APACHE II: Acute Physiology and Chronic Health Evaluation II; ARDS: Acute Respiratory Distress Syndrome; BMI: Body Mass Index; ICU: Intensive Care Unit; IQR: Interquartile Range; mNUTRIC: modified Nutrition Risk in Critically Ill; SD: Standard Deviation; SOFA: Sequential Organ Failure Assessment score; TBSA: Total Burn Surface Area.

3.3. Energy requirements

IC was used to determine energy requirements for 6% of patients; the best site used IC for 93.3% of patients and the worst did not use it at all. The most popular method for estimating energy requirements was based on body weight (22.3%), being followed by the Harris–Benedict equation [17] (16.3%) and the Milner formula (12.4%), whereas for the rest, several other ways were used (Supplementary Table 3). Actual dry body weight was used for the estimation of energy requirements in the majority of patients (55.5%), followed by the use of estimated dry body weight in 21.9% of the cases.

3.4. Meeting energy needs

Overall, on average the included 283 patients were prescribed 2648.4 ± 738.8 kcal/d or 32.3 ± 9.2 kcal/kg/d and received 64.9 ± 40.0% of this goal over the 12 days of observation (Table 4). Figure 2 illustrates the actual received average, best and worst performances in regard to the prescribed calories across the 12 days of observation (site average: 65.3%; 80.2% for best and 42.0% for worst site).

Provision of at least 80% of energy needs was achieved within 48–72 h per the SCCM/ASPEN guidelines in 35.3% of patients, with the best site achieving this in 80.0% of patients and the worst completely failing in this (0.0%).

In 39.2% of patient-days, EN was held or interrupted; reasons can be seen in Table 5. Main reasons that led to EN interruptions were either an operating room (33.0%) or bedside (25.8%) procedure, whereas EN intolerance was reported in 14.8% of cases.

3.5. Protein requirements

Protein requirements were calculated based on each patient's actual dry body weight for 42.6% of the participants, followed by Hamwi's [18] ideal body weight formula in 19.8% of the sample. The range of 1.5–2.0 g/kg/d was prescribed in 33.9% of patients. The protein prescription was higher than 2.0 g/kg/d for 31.1% of patients, and 35.0% of patients were prescribed less than 1.5 g/kg/d.

3.6. Meeting protein needs

Overall, participating sites prescribed 149.1 ± 52.1 g of protein per day, which translated to 1.81 ± 0.61 g protein/kg/d and the average adequacy of total protein over the 12 days of observation was 65.6 ± 42.1% (Table 4). When examining the amount of protein received, 19.2% of the patient-days had actual intake within 1.5–2.0 g protein/kg/d, with the best site achieving this for 39.8% and the worst for 7.9% of their patient-days (Table 3). Figure 3 illustrates the actual received average and the performance of the best and worst sites during the 12 days of observation (site average: 65.4%; 87.3% for best and 43.6% for worst site). Provision of at least 80% of needs was achieved within 48–72 h per the SCCM/ASPEN guidelines in 34.3% of patients (80.0% for best and 0.0% for worst site).

3.7. Micronutrient supplementation

Glutamine was administered in 22.4% of patient-days (highest site 61.8%, lowest site 0.0). Vitamin C was supplemented for 61.7% of patient-days (best site: 98.7%, worst site: 2.4%). Zinc was supplemented for 44.2% of patient-days (best site: 97.0%, worst site: 0.0%). Selenium was supplemented for 24.8% of patient-days (best site: 82.3%, worst site: 0.0%). Provisions were low for IV Vitamin C (17.5% of patient-days, highest site 98.7%, lowest site 0.0%), zinc (15.5% of

Table 3
Summary of findings regarding adherence to the ESPEN and SCCM/ASPEN guidelines for the nutritional management of severe burn patients.

Recommendation		Society Guidelines		Overall adherence			
		ESPEN	SCCM/ASPEN	Overall Patient-Days	Site average	Site Range	
						Best site	Worst site
Feeding route	Suggested feeding route: *EN*	yes	yes	90.5%	90.4%	97.0%	79.2%
EN initiation	*Within 12 h from admission*	yes	–	35%	36.8%	90.0%	5.0%
	Within 4-6 h from admission	–	yes	18.7%	20.1%	70.0%	0.0%
Energy needs	Measurement of Requirements: per *indirect calorimetry*	yes	yes	6.0%	7.7%	93.3%	0.0%
	Time point for meeting needs: *80% of goal energy within 48-72h*	–	yes	35.3%	37.7%	80.0%	0.0%
Protein needs	Received *1.5-2.*0 g/kg/d	yes	yes	19.2%	19.2%	39.8%	7.9%
	Time point for meeting needs: *80% of goal protein within 48-72h*	–	yes	34.3%	36.6%	80.0%	0.0%
	*Received 1.5-2.*0 g/kg/d *"or higher"*	–	yes	35.6%	33.5%	61.1%	15.2%
Supplementation	Glutamine, either route: *0.*3 g/kg/d	yes	–	22.4%	18.5%	61.8%	0.0%
	Glutamine: *EN/PO*	–	–	22.4%	18.5%	61.8%	0.0%
	Glutamine: *IV*	–	–	<0.1%	<0.1%	N/A	N/A
	Vitamin C: *either route*	yes	yes	61.7%	57.7%	98.7%	2.4%
	Vitamin C: *EN/PO*	–	–	45.4%	42.7%	83.7%	0.0%
	Vitamin C: *IV*	–	–	17.5%	16.0%	98.7%	0.0%
	Zn: *either route*	yes	yes	44.2%	41.6%	97.0%	0.0%
	Zn: *EN/PO*	–	–	31.7%	30.0%	76.7%	0.0%
	Zn: *IV*	–	–	15.5%	13.9%	97.0%	0.0%
	Se: *either route*	yes	yes	24.8%	19.9%	82.3%	0.0%
	Se: *EN/PO*	–	–	12.4%	8.6%	50.8%	0.0%
	Se: *IV*	–	–	14.5%	12.9%	82.3%	0.0%
	No recommendation on Probiotics	–	–	2.6%	3.1%	34.4%	0.0%
Glucose control	Glucose levels: *4.5-*8 mmol/L = *81–*144 mg/dL	yes	–	57.1%	56.8%	68.0%	48.5%
	Glucose levels: *7.8 or 8.3-*10 mmol/L = *140 or 150–*180 mg/dL	–	yes	24.2%	24.1%	31.7%	15.0%

EN: Enteral Nutrition; ESPEN: European Society for Clinical Nutrition and Metabolism; IV: Intravenous; PO: Per Os; Se: Selenium; SCCM/ASPEN: Society of Critical Care Medicine/American Society for Parenteral and Enteral Nutrition; Zn: Zinc.

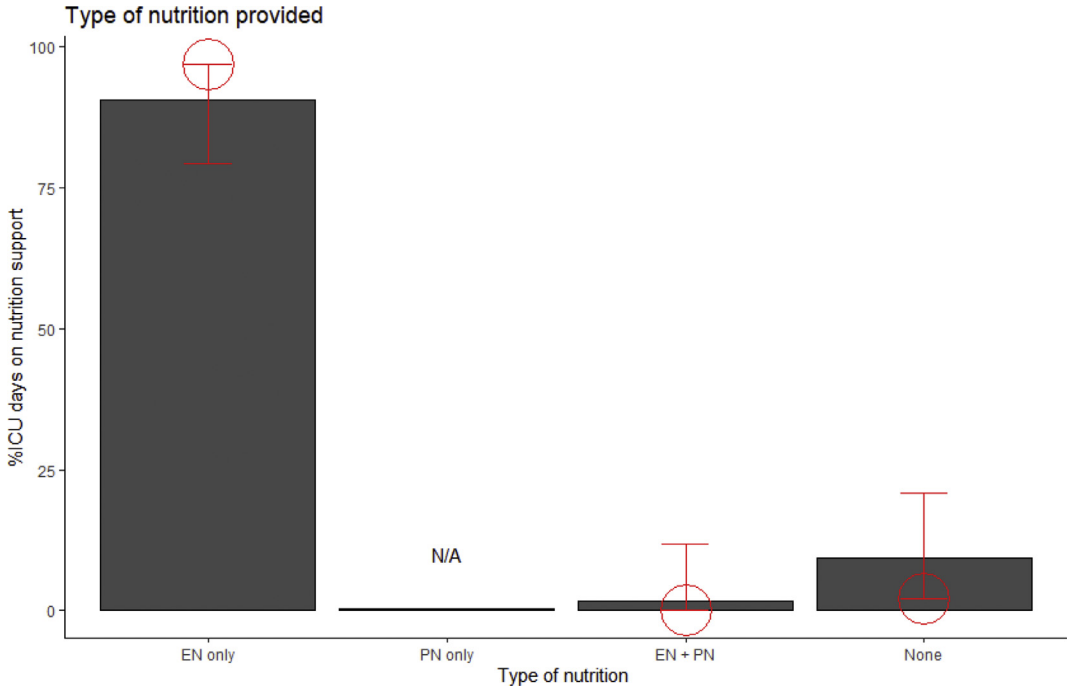

Fig. 1. Lowest edge of error bars indicate the worst performance while the highest indicates best performance. 'None' refers to number of patients with neither EN nor PN, regardless of oral intake. The best achievable practices are circled.

patient-days, highest site 97.0%, lowest site 0.0%), selenium (14.5% of patient-days, highest site 82.3, lowest site 0.0%), and glutamine (<0.1% of patient-days). High intakes of IV vitamin C (>10 mg/kg/day) were achieved in a total of 5% of patient-days, while levels of >60 mg/kg/day were only reached on one patient-day.

Finally, despite the absence of specific information available for the use of probiotics, in 2.6% of patient-days such was used, with a range of 0–34.4% for all sites. Overall, detailed information on the supplementary provision of pharmaconutrients can be seen in Supplementary Table 4.

3.8. Glucose control

The daily morning glucose level was 144.5 ± 40.9 mg/dL (site average range, 134.4–151.5 mg/dL), with 42.1% of days higher than 144 mg/dL and 12.5% of days higher than 180 mg/dL. ESPEN's

Table 4
Prescribed (goal) versus received energy and protein.

	Targeted, *mean (SD)*	Received, *mean (SD)*	Site average	Best site	Worst site
	n = 283 patients	*n=2849 patient-days*	*n=14 sites*		
Energy requirements, kcal/d	2648.4 (738.8)	1717.9 (1149.0)	1657.9	2418.4	1145.1
Protein requirements, g/d	149.1 (52.1)	98.0 (72.7)	92.7	159.5	68.5
Energy per kg of BW, kcal/kg/d	32.3 (9.2)	21.1 (14.5)	20.7	29.0	14.1
Protein per kg of BW, kcal/kg/d	1.81 (0.61)	1.2 (0.89)	1.15	1.79	0.83
Nutritional adequacy for energy, %	N/A	64.9 (40.0)	65.3	80.2	42.0
Nutritional adequacy for protein, %	N/A	65.6 (42.1)	65.4	87.3	43.6

BW: Body Weight; SD: Standard Deviation.

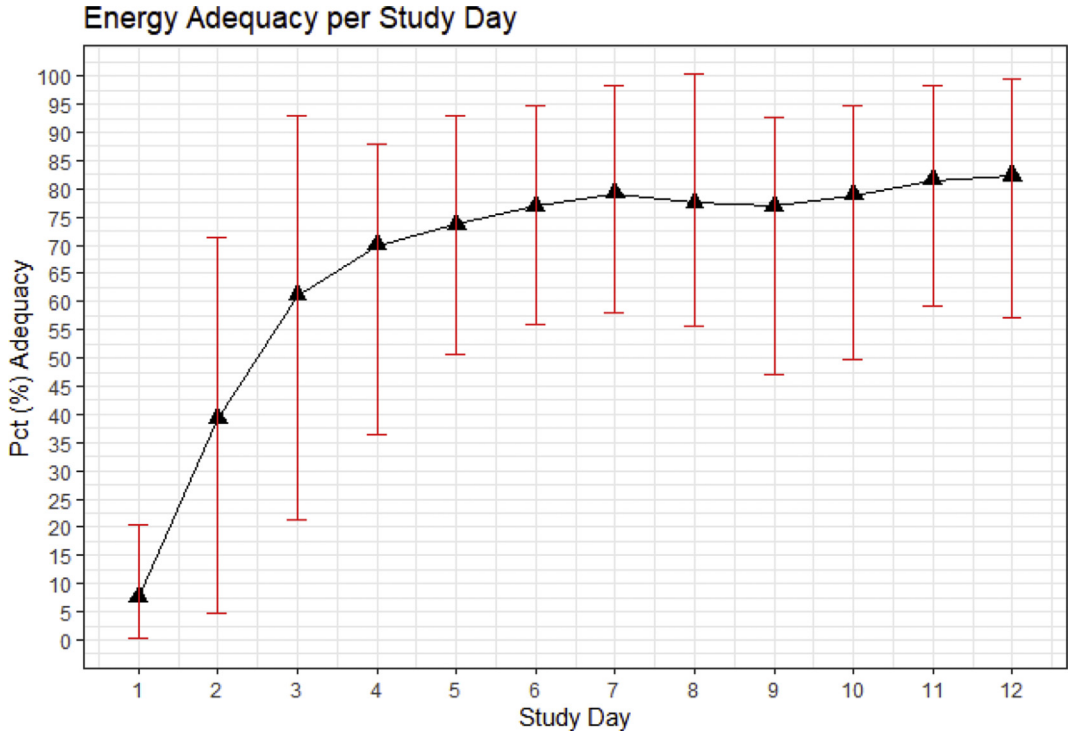

Fig. 2. The amount of calories received by EN and PN as a percentage of the calories prescribed at baseline assessment in all patients.

recommendation to keep glucose levels between 81 and 144 mg/dL was met for 57.1% of patient-days, as measured by the morning glucose level (best site: 68.0%, worst site: 48.5%). SCCM/ASPEN's recommendation to keep glucose levels between 140 or 150–180 mg/dL was adhered to for 24.2% of patient-days (best site: 31.7%, worst site: 15.0%). Insulin was administered in a total of 1347 patient-days, of which 223 (16.6%, site range: 0.0%–41.3%) reported more than 96 units/day.

4. Discussion

We conducted a prospective, observational study in 14 different ICUs to compare nutrition practices among burn units and determine the "best achievable" nutrition practices across participating sites. We observed large gaps between most of the Guidelines examined and current practices achieved.

According to the Guidelines [2,3,5], EN is the preferred feeding route for burn patients, conferring several advantages over PN. In particular, early EN commencement is associated with reduced infection [19], cost [20], and length of stay [21], shortened hypermetabolic phase [22–24], protection of the gastrointestinal track [25], and improved nutrient adequacy [26]. This superiority of EN appears to be acknowledged by the majority involved in the

Table 5
Reasons Enteral Nutrition Feeds interrupted.

	Total (%) n = 999 (39.2%)[c]
Number of patient-days	
Fasting for operating room procedure	330 (33.0%)
Fasting for bedside procedure	258 (25.8%)
EN Intolerance[a]	148 (14.8%)
No enteral access available/enteral access lost, displaced or malfunctioning	80 (8.0%)
Trial of oral intake	73 (7.3%)
Inotropes, vasopressor requirement	27 (2.7%)
Dressing Change	21 (2.1%)
Subject deemed too sick to continue enteral feeding	18 (1.8%)
Fasting for radiology suite procedure	18 (1.8%)
Fasting for administration of medications	11 (1.1%)
Other[b]	15 (1.5%)

CPAP: Continuous Positive Airway Pressure; EN: Enteral Nutrition; GI: Gastrointestinal.

[a] Increased gastric residuals (n = 60.8%), vomiting/emesis (n = 19.6%), increased abdominal girth or abdominal distension (n = 10.1%), subjective discomfort (n = 7.4%), diarrhea or other (n = 2.1%).

[b] Including GI bleeding (2), Patient agitation (2), Unknown (2), Acute arterial bleeding (1), CPAP/vent weaning (1), Hydrotherapy (shower table) (1), Patient on CPAP (1).

[c] In a total of 2550 patient-days.

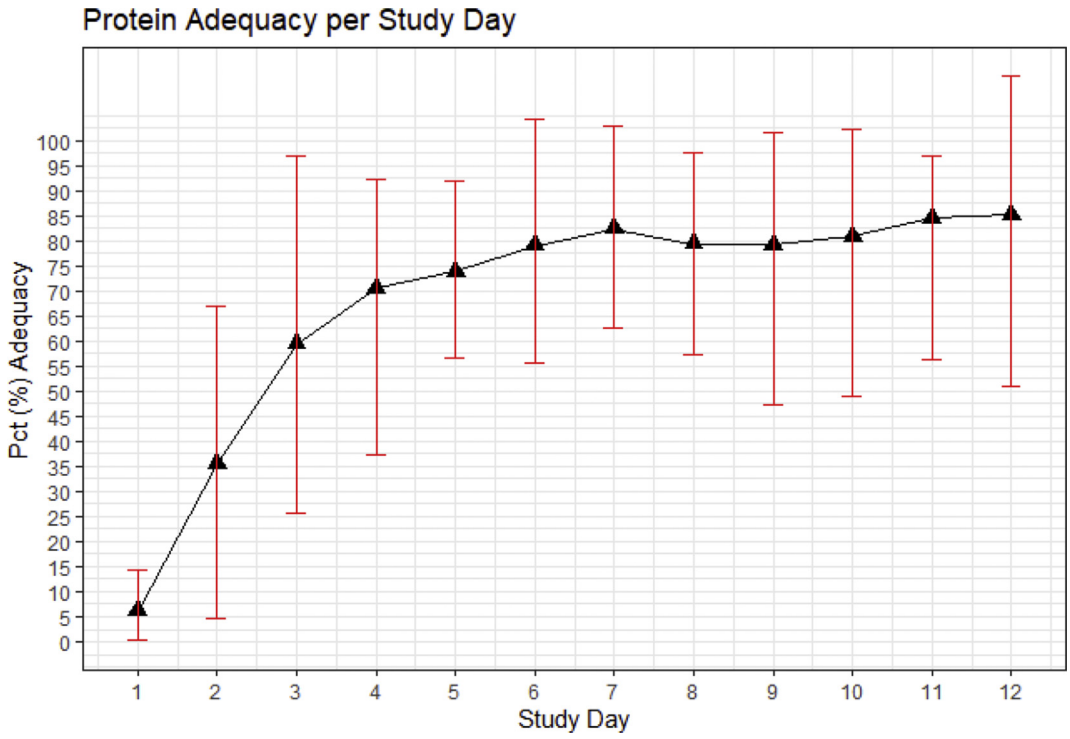

Fig. 3. The amount of protein received by EN and PN as a percentage of the protein prescribed at baseline assessment in all patients.

nutrition support provided by burn centers and was used for 90.5% of patient-days.

SCCM/ASPEN [2,5] recommends initiating EN within 4–6 h of injury. In our sample EN was initiated within 4–6 h of admission for less than 1 out of every 5 patients. The best site was able to achieve EN initiation within 4–6 h of admission in 70% of patients, indicating that this may be one of the more difficult guidelines to follow, as the recommendation is initiating EN within 4–6 h of *injury*, rather than within 4–6 h of *admission*. Only approximately one-third of patients received EN within 12 h of admission to the ICU, despite ESPEN guidelines. However, the best site was able to achieve EN initiation within 12 h of admission in 90% of patients so improvements in timeliness of administration of EN are possible.

Precise estimation of the caloric requirements of burn patients is important for nutritional management in order to optimize wound healing [27,28]. Measured energy needs of adult burn patients have been shown to be increased by 160% on average, and no predictive equation is considered accurate [28–30]. As a result, the Guidelines [3,5] advocate for the measurement of energy requirements via IC at several time points during hospitalization to match the dynamic changes in nutrient needs. In our study, the best site was able to achieve measurements via IC in 93.3% of patients, with the remaining being estimated through a variety of equations.

The Guidelines recommend goal protein prescription of 1.5–2.0 g/kg/d ("or higher" per SCCM/ASPEN). A 31.0% of patients were prescribed >2.0 g/kg/d and only 19.2% of the recorded patient-days were within 1.5–2.0 g/kg/d (best site: 39.8%, worst site: 7.9%), leaving the majority of patient-days with an inappropriately low protein administration.

According to the SCCM/ASPEN guidelines [2,5], 80% of energy and protein goals should be provided within 3 days of EN initiation; any delays in initiation have been shown to lead to poorer outcomes [31]. In our study, this recommendation was followed in approximately 1/3 of cases. The fact that one site was able to achieve this quality indicator in at least 80% of patients suggests that systematic improvements in nutritional delivery is possible.

The concept of Volume Based Feedings, as recently presented by the PEPuP protocol, seems to increase the probability of meeting the nutritional goals (in both energy and protein) in a safe way, also related to less episodes of hyperglycemia and lower use of PN [32].

The Guidelines suggest the use of supplementation for vitamin C, zinc, and selenium among burn patients. ESPEN recommends glutamine supplementation; however, SCCM/ASPEN recommends against and 22.4% of the patient-days received supplementation. The on-going, international, multicenter, double-blind, pragmatic, randomized controlled trial of patients with severe burns (RE-ENERGIZE) is the largest so far, and its results will shed more light on the effects on glutamine in burn patients [33].

With the exception of vitamin C, micronutrient supplements were provided in less than half of the total patient-days. However, even in the case of Vitamin C doses submitted were very low (at a supplemental level) and cannot be considered to demonstrate any pharmacological action. Only 1 patient received >60 mg/kg/h, whereas studies using IV vitamin C at 200 mg/kg/d (CITRUS ALI Trial) [34] failed to show an improvement in dysfunction scores or alter markers of inflammation and vascular injury among patients with sepsis and acute respiratory distress syndrome.

ESPEN [3] advocates for tight glycemic control among major burn patients, targeting a goal blood glucose between 81 and 144 mg/dL. Overall, 57.1% of patient-days were within the ESPEN goal at the morning glucose check (best site: 68.0% of patient-days). Although SCCM/ASPEN does not suggest any burn-specific optimal glucose range, they provide recommendations for 140 or 150–180 mg/dL for critically ill patients in general [2,5]. Overall, 24.2% of the patient-days were within the SCCM/ASPEN recommended target (best site: 61.1% of patient-days). According to Porter [27], post-burn glucose dysregulation is the result of diminished central and peripheral insulin sensitivity. As such, any strategies for improving glucose control may lead to

faster recovery and reduced mortality [27]. However, a recent meta-analysis demonstrated only neutral results for short-term or 3- or 6-month mortality and risk of sepsis among ICU patients on intensive glycose control, and these results remained constant among different study settings including surgical ICUs, medical ICUs or mixed ICUs [35]. Moreover, for a noteworthy number of patient-days (223/1347, 16.6%, site range: 0.0%–41.3%) insulin administration was reported to be more than 96 units/day, which clearly exceeds traditional standards of metabolic tolerance and is greater than normal non-burn insulin requirements.

We did not ask the sites whether they were intending to comply to those or other guidelines, but we thought this was not necessary as from a clinical point of view compliance with best practice statements is a prerequisite for good clinical practice.

We acknowledge that it can be seen as a limitation that the ICU participating in our sample are not a representative sample of ICU across the globe. This is mainly attributed to the fact that participation to the study was voluntary and this could be related to a potential response bias, and therefor the evidence-practice gap found here, might be larger in reality. Despite, that all sample centers are located in Anglo Saxon countries, and even if taking into account the cultural and medical specificities that come with this, we still think that our study has a strength, which is that it does observe actual nutrition practices among a large sample of ICUs and compares them to the evidence-based guidelines. We also believe that the benchmarking aspect of this study highlights “best achievable” practice.

We recommend investigating strategies for removing the barriers to achieving the Guidelines within individual institutions. Clearly, generating high levels of evidence will also help with adherence to these clinical practice guidelines.

5. Conclusions

Collectively, the present findings identified an overall significant lack of compliance to the Guidelines for nutrition support. The results reveal a great variability in the estimation of energy requirements, optimal timing of EN initiation, and lack of consensus concerning the energy and protein needs of patients. Additionally, non-adherence was observed with glycemic control and administration of micronutrient supplements.

We acknowledge that the inconsistency in standards and procedures of care among different centers might have resulted in a significant variability of the data. However, a strength of the study is that “real life” data was reported, observing actual nutrition practices among a large sample of ICUs. Undoubtedly, setting a goal of 100% adherence to the Guidelines may not be practical. However, the value of this paper is in defining a realistic, achievable performance goal, which is important from a quality improvement perspective. It must be noted that goals of this study were not to explain why this variation in adherence exists and not to explain the mechanisms by which the best practice is achieved. Such an analysis may offer further insights in how to improve performance [7] by underlining factors that could act as barriers and/or enablers.

Statement of authorship

MC lead the writing of the manuscript and participated in the statistical analyses, EB lead the statistical analyses, BES, CS, AFR participated in various stages of the writing of the manuscript, DKH conducted the idea of the study and reviewed each version of the manuscript.

Formatting of funding sources

NA.

Conflict of interest

No conflict of interest.

Acknowledgements

We would like to thank Dr. M. Grammatikopoulou for her input in the very first draft of the paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnu.2020.04.023.

References

[1] Clark A, Imran J, Madni T, Wolf SE. Nutrition and metabolism in burn patients. Burns Trauma 2017;5:11.
[2] McClave SA, Taylor BE, Martindale RG, Warren MM, Johnson DR, Braunschweig C, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: society of critical care medicine (SCCM) and American society for parenteral and enteral nutrition (A.S.P.E.N.). J Parenter Enter Nutr 2016;40:159–211.
[3] Rousseau AF, Losser MR, Ichai C, Berger MM. ESPEN endorsed recommendations: nutritional therapy in major burns. Clin Nutr 2013;32:497–502.
[4] Snell JA, Loh NH, Mahambrey T, Shokrollahi K. Clinical review: the critical care management of the burn patient. Crit Care 2013;17:241.
[5] Taylor BE, McClave SA, Martindale RG, Warren MM, Johnson DR, Braunschweig C, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: society of critical care medicine (SCCM) and American society for parenteral and enteral nutrition (A.S.P.E.N.). Crit Care Med 2016;44:390–438.
[6] Williams FN, Branski LK, Jeschke MG, Herndon DN. What, how, and how much should patients with burns be fed? Surg Clin 2011;91:609–29.
[7] Cahill NE, Dhaliwal R, Day AG, Jiang X, Heyland DK. Nutrition therapy in the critical care setting: what is “best achievable” practice? An international multicenter observational study. Crit Care Med 2010;38:395–401.
[8] Hegazi RA, Wischmeyer PE. Clinical review: optimizing enteral nutrition for critically ill patients-a simple data-driven formula. Crit Care 2011;15:234.
[9] Heyland DK, Lemieux M, Shu L, Quisenberry K, Day AG. What is “best achievable” practice in implementing the enhanced protein-energy provision via the enteral route feeding protocol in intensive care units in the United States? Results of a multicenter, quality improvement collaborative. J Parenter Enter Nutr 2016;42(2):308–17. https://doi.org/10.1177/0148607116673301.
[10] Knaus WA, Draper EA, Wagner DP, Zimmerman JE. Apache II: a severity of disease classification system. Crit Care Med 1985;13:818–29.
[11] Moreno R, Vincent JL, Matos R, Mendonca A, Cantraine F, Thijs L, et al. The use of maximum SOFA score to quantify organ dysfunction/failure in intensive care. Results of a prospective, multicentre study. Work Gr Sepsi Rel Prob ESICM Inten Care Med 1999;25:686–96.
[12] Ladhani HA, Sajankila N, Zosa BM, He JC, Yowler CJ, Brandt C, et al. Utility of Sequential Organ Failure Assessment score in predicting bacteremia in critically ill burn patients. Am J Surg 2018;215:478–81.
[13] Giretzlehner M, Dirnberger J, Owen R, Haller HL, Lumenta DB, Kamolz LP. The determination of total burn surface area: how much difference? Burns. J Inter Soc Burn Inj 2013;39:1107–13.
[14] Tobiasen J, Hiebert JM, Edlich RF. The abbreviated burn severity index. Ann Emerg Med 1982;11:260–2.
[15] Heyland DK, Dhaliwal R, Jiang X, Day AG. Identifying critically ill patients who benefit the most from nutrition therapy: the development and initial validation of a novel risk assessment tool. Crit Care 2011;15:R268.
[16] Heyland DK, Cahill N, Day AG. Optimal amount of calories for critically ill patients: depends on how you slice the cake! Crit Care Med 2011;39:2619–26.
[17] Harris JABF. A biometric study of basal metabolism in man. 1919. p. 32–40.
[18] Hamwi G. Therapy: changing dietary concepts. 1964.
[19] Lu G, Huang J, Yu J, Zhu Y, Cai L, Gu Z, et al. Influence of early post-burn enteral nutrition on clinical outcomes of patients with extensive burns. J Clin Biochem Nutr 2011;48:222–5.
[20] Chen Z, Wang S, Yu B, Li A. A comparison study between early enteral nutrition and parenteral nutrition in severe burn patients. Burns : J Inter Soc Burn Inj 2007;33:708–12.
[21] Mosier MJ, Pham TN, Klein MB, Gibran NS, Arnoldo BD, Gamelli RL, et al. Early enteral nutrition in burns: compliance with guidelines and associated

outcomes in a multicenter study. J Burn Care Res : Off Pub Am Burn Asso 2011;32:104–9.
[22] Hart DW, Wolf SE, Chinkes DL, Beauford RB, Mlcak RP, Heggers JP, et al. Effects of early excision and aggressive enteral feeding on hypermetabolism, catabolism, and sepsis after severe burn. J Trauma 2003;54:755–61. discussion 61-4.
[23] Williams FN, Herndon DN, Jeschke MG. The hypermetabolic response to burn injury and interventions to modify this response. Clin Plast Surg 2009;36:583–96.
[24] Williams FN, Jeschke MG, Chinkes DL, Suman OE, Branski LK, Herndon DN. Modulation of the hypermetabolic response to trauma: temperature, nutrition, and drugs. J Am Coll Surg 2009;208:489–502.
[25] Xiao SC, Zhu SH, Xia ZF, Lu W, Wang GQ, Ben DF, et al. Prevention and treatment of gastrointestinal dysfunction following severe burns: a summary of recent 30-year clinical experience. World J Gastroenterol 2008;14:3231–5.
[26] Gottschlich MM, Jenkins ME, Mayes T, Khoury J, Kagan RJ, Warden GD. The 2002 Clinical Research Award. An evaluation of the safety of early vs delayed enteral support and effects on clinical, nutritional, and endocrine outcomes after severe burns. J Burn Care Rehabil 2002;23:401–15.
[27] Porter C, Tompkins RG, Finnerty CC, Sidossis LS, Suman OE, Herndon DN. The metabolic stress response to burn trauma: current understanding and therapies. Lancet (London, England) 2016;388:1417–26.
[28] Rodriguez NA, Jeschke MG, Williams FN, Kamolz LP, Herndon DN. Nutrition in burns: galveston contributions. J Parenter Enter Nutr 2011;35:704–14.
[29] Allard JP, Pichard C, Hoshino E, Stechison S, Fareholm L, Peters WJ, et al. Validation of a new formula for calculating the energy requirements of burn patients. J Parenter Enter Nutr 1990;14:115–8.
[30] Dickerson RN, Gervasio JM, Riley ML, Murrell JE, Hickerson WL, Kudsk KA, et al. Accuracy of predictive methods to estimate resting energy expenditure of thermally-injured patients. J Parenter Enter Nutr 2002;26:17–29.
[31] Wolf SE, Rose JK, Desai MH, Mileski JP, Barrow RE, Herndon DN. Mortality determinants in massive pediatric burns. An analysis of 103 children with > or = 80% TBSA burns (> or = 70% full-thickness). Ann Surg 1997;225:554–65. discussion 65-9.
[32] Prest PJ, Justice J, Bell N, McCarroll R, Watson CM. A volume-based feeding protocol improves nutrient delivery and glycemic control in a surgical trauma intensive care unit. J Parenter Enter Nutr 2019. https://doi.org/10.1002/jpen.1712.
[33] Heyland DK, Wischmeyer P, Jeschke MG, Wibbenmeyer L, Turgeon AF, Stelfox HT, et al. A RandomizEd trial of ENtERal Glutamine to minimIZE thermal injury (The RE-ENERGIZE Trial): a clinical trial protocol. Scars, Burns Healing 2017;3. 2059513117745241.
[34] Fowler 3rd AA, Truwit JD, Hite RD, Morris PE, DeWilde C, Priday A, et al. Effect of vitamin C infusion on organ failure and biomarkers of inflammation and vascular injury in patients with sepsis and severe acute respiratory failure: the CITRIS-ALI randomized clinical trial. J Am Med AssocJ Am Med Assoc 2019;322:1261–70.
[35] Fu Y, Sun Y, Zhang J, Cheng Y. Intensive glucose control for critically ill patients: an updated meta-analysis. Endocr Connect 2018;7:1288–98.