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Nutrition During Intensive Care

Edited by Mahsa Jalili

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Meet the editor

Mahsa Jalili, Ph.D., is an assistant professor in clinical nutrition at the Department of Nutrition, Exercise, and Sports at the University of Copenhagen in Denmark. With over a decade of experience in nutrition and molecular biology, she specializes in the intersection of nutrition and disease, employing techniques such as clinical trials, animal experiments, omics, and data analysis. Her research includes over 20 published papers and spans nutrition, immunology, omics, and epidemiology. Mahsa's work aims to elucidate the molecular mechanisms of nutrients and diet therapy, focusing on improving nutrition care and reducing any type of malnutrition in patients. Her latest book compiles current evidence on nutrition for ICU patients, aiming to enhance understanding among clinicians, nurses, and anyone interested in nutrition therapy and its challenges in critical care. Additionally, Mahsa is a dedicated mother, balancing her professional and personal life with grace.

Contents

Preface

As the editor of this book, *Nutrition During Intensive Care*, I would like to introduce myself and share the journey that led to the creation of this book. My academic background includes a bachelor's, master's, and PhD in clinical nutrition and diet therapy. Over the past decade, I have immersed myself in the field of nutrition, dedicating my career to both teaching and research. My work spans human studies and animal experiments, focusing on how nutrition can influence various diseases and improve patient outcomes.

My passion for clinical nutrition stems from a deep-seated belief in its potential to enhance the quality of life for patients, especially those in critical care. Throughout my career, I have been driven by the desire to understand the mechanisms by which nutrients affect health and disease. This book represents a culmination of my efforts to gather and present the most current knowledge in clinical nutrition for patients in intensive care units (ICUs).

This book's primary aim is to address the practical challenges faced by clinical nutritionists and healthcare professionals working in ICUs. Managing the nutritional needs of ICU patients, particularly those with multiple comorbidities requires a nuanced approach. Timing, nutrient–drug interactions, and the adverse effects of polypharmacy are critical factors that must be carefully managed to ensure patient survival and recovery. The adverse effects of multiple medications can significantly impact gastrointestinal physiology, appetite, and regulatory hormones, posing additional challenges for clinicians.

During my years of practice, I have encountered numerous patients who did not receive adequate nutritional support during their hospital stays. This experience has reinforced my commitment to providing evidence-based nutritional guidance and supplementation to prevent deficiencies and reduce the burden on patients. I hope this book will serve as a valuable resource for healthcare professionals, offering practical insights and strategies to improve patient care in the ICU.

I would like to extend my heartfelt gratitude to all the authors who contributed to this book. Their dedication and expertise have been instrumental in compiling this collection of current knowledge on clinical nutrition for ICU patients. While this book does not cover every aspect of nutrition and metabolism in ICU settings, it provides a robust foundation to support healthcare professionals in meeting the urgent needs of their patients.

In this book, we explore a range of topics, including nutritional assessment in the ICU, enteral and parenteral nutrition, the unique challenges faced by obese patients in the ICU, and the critical role of thiamin for ICU patients. Each chapter offers

practical advice and evidence-based recommendations that can be implemented in hospital settings to enhance patient survival and improve the quality and quantity of nutritional intake.

I encourage all healthcare professionals working with ICU patients to read this book. Although it may not be perfect, it offers numerous practical points that can be applied in clinical practice. We can develop tailored nutritional strategies that support their recovery and overall well-being by considering patients' medical histories, medications, and comorbidities.

Thank you for your interest in this book. I hope it is a valuable tool in your efforts to provide optimal nutritional care for ICU patients.

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Chapter 1

Introductory Chapter: Nutrition During Intensive Care

Mahsa Jalili

1. Introduction

Nutrition plays a critical role in the management and recovery of patients in intensive care units (ICUs) [1]. Critical illness places physiological stress on the body, and the demands of healing increase the need for a tailored nutritional strategy. Such an approach is vital to improving patient outcomes. This introductory chapter explores the importance of nutrition in the ICU, the challenges faced in providing adequate nutritional support, and the strategies employed to meet the nutritional needs of critically ill patients [2].

2. Importance of nutrition in intensive care

Proper nutrition is essential for maintaining the body's immune function, muscle mass, and overall energy levels. In critically ill patients, malnutrition can lead to a weakened immune response, increased susceptibility to infections, delayed wound healing, and prolonged hospital stays. Therefore, ensuring adequate nutritional intake is a cornerstone of intensive care management [3].

2.1 Challenges in nutritional support

Providing optimal nutrition in the ICU is fraught with challenges. Critically ill patients often experience altered metabolic states, including hypermetabolism and catabolism, which increase their nutritional requirements [4]. Additionally, factors such as gastrointestinal dysfunction, sedation, and mechanical ventilation can complicate the delivery of enteral or parenteral nutrition. Assessing the nutritional status of ICU patients is also challenging due to fluid imbalances and the presence of edema, which can mask true body weight and composition [5].

2.2 Nutritional assessment and monitoring

Accurate assessment of nutritional needs is vital for developing an effective nutrition plan. This involves evaluating the patient's baseline nutritional status, current metabolic demands, and any underlying conditions that may affect nutrient absorption or utilization. Tools such as indirect calorimetry, a technique that measures energy expenditure, is often used to tailor nutritional interventions, and biochemical

markers, like serum albumin and prealbumin levels, are often used to guide nutritional interventions [6].

2.3 Enteral vs. parenteral nutrition

Enteral nutrition (EN), delivered directly to the gastrointestinal tract, is generally preferred over parenteral nutrition (PN) due to its association with better outcomes, including reduced infection rates and preservation of gut integrity. However, when EN is not feasible or sufficient, PN, which provides nutrients intravenously, becomes necessary. Clinical nutritionists choose between EN and PN based on the patient's condition, gastrointestinal function, and the risk of complications [7].

2.4 Strategies for nutritional support

Nutrition support is crucial for managing critically ill patients. Several strategies are employed to optimize nutritional support in the ICU [8]. These include:

- *Early initiation*: Starting nutritional support within 24–48 hours of ICU admission to prevent malnutrition, especially for patients at risk.
- *Individualized plans*: Tailoring nutrition plans to meet the specific needs of each patient, considering factors such as age, weight, underlying conditions, and metabolic demands.
- *Monitoring and adjustment*: Regularly monitoring nutritional intake and metabolic response and adjusting the nutrition plan as needed to ensure adequate nutrient delivery and minimize complications.

3. Current issues for nutrition support

Recent research into ICU nutrition support has focused on strategies for continuous glucose monitoring and optimizing the timing of parenteral nutrition (TPN). These strategies are crucial for improving patient outcomes and maintaining glycemic control. The timing and adequacy of nutritional support directly impact glycemic control and improve patient outcomes. Careful monitoring of these factors is essential for optimal management. Precisely formulated and safely administered nutritional support is crucial in critical care units. Despite gradual progress, the field faces ongoing challenges, such as the rise in malnutrition, obesity, and metabolic syndrome. Well-planned research is essential to guide future clinical trials and develop evidence-based guidelines for all subgroups of ICU patients. This book explores the recent advancements and future potential of nutrition support, emphasizing the importance of early and adequate feeding based on individual nutritional screening and interactions with medications, particularly through parenteral and enteral nutrition for malnourished patients unable to receive sufficient oral nutrition [9].

Over the past decades, there have been significant increases in obesity, metabolic syndrome, and cardiometabolic disorders in ICU. These conditions increase surgical risks and require careful management by ICU clinical nutritionists. Abdominal fat is linked to insulin resistance and higher mortality risk. Metabolic syndrome is a main concern for ICU patients, considering the role of ectopic fat in insulin resistance and

higher risk for comorbidities. Some studies recommend that protein-sparing hypocaloric formulas and regular glucose monitoring can reduce mortality in vulnerable overweight and obese ICU patients. Hypocaloric nutrition, which provides fewer calories than usual, can aid in managing metabolic stress. Nutritional support should be given in hypocaloric doses, with sufficient protein to help wound healing and enhance the immune system. A plan of physical activity like resistance training before surgery can improve outcomes for patients [4, 9, 10].

4. Conclusion

Nutrition during intensive care is a complex but crucial aspect of patient management. By understanding the importance of nutrition, recognizing the challenges, and employing effective strategies, healthcare providers can significantly improve the outcomes for critically ill patients. This chapter sets the stage for a deeper exploration of the specific nutritional interventions and protocols used in the ICU, aiming to provide a comprehensive guide for optimizing patient care through nutrition.

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References

[1] Casaer MP, Van den Berghe G. Nutrition in the acute phase of critical illness. New England Journal of Medicine. 2014;**370**(13):1227-1236

[2] Schulman RC, Mechanick JI. Metabolic and nutrition support in the chronic critical illness syndrome. Respiratory Care. 2012;**57**(6):958-978

[3] Sharma K, Mogensen KM, Robinson MK. Pathophysiology of critical illness and role of nutrition. Nutrition in Clinical Practice. 2019;**34**(1):12-22

[4] Patiño JF, de Pimiento SE, Vergara A, Savino P, Rodríguez M, Escallón J. Hypocaloric support in the critically ill. World Journal of Surgery. 1999;**23**(6):553-559

[5] Sabol VK. Nutrition assessment of the critically ill adult. AACN Advanced Critical Care. 2004;**15**(4):595-606

[6] Golts E, Choi J, Wilson WC, Fuchs S, Angle N. Nutritional and metabolic evaluation and monitoring. Trauma. 1st ed. Imprint CRC Press; 2007:14. eBook ISBN: 9780429118821

[7] Pironi L, Arends J, Bozzetti F, Cuerda C, Gillanders L, Jeppesen PB, et al. ESPEN guidelines on chronic intestinal failure in adults. Clinical Nutrition. 2016;**35**(2):247-307

[8] Bally MR, Yildirim PZB, Bounoure L, Gloy VL, Mueller B, Briel M, et al. Nutritional support and outcomes in malnourished medical inpatients: A systematic review and meta-analysis. JAMA Internal Medicine. 2016;**176**(1):43-53

[9] Blackburn GL, Wollner S, Bistrian BR. Nutrition support in the intensive care unit: An evolving science. Archives of Surgery. 2010;**145**(6):533-538

[10] Hoffer LJ. High-protein hypocaloric nutrition for non-obese critically ill patients. Nutrition in Clinical Practice. 2018;**33**(3):325-332

Chapter 2

Nutrition Screening and Assessment among Critically Ill Patients

Neha Bakshi, Amisha Khurana and Shanza Ferozi

Abstract

Malnutrition occurs in critically ill patients with characteristic hypermetabolic responses and physiological stresses such as increased energy expenditure, protein catabolism, insulin resistance, fluid shifts, and inflammatory response. Severe complications are common among these patients which includes immune dysfunction, poor wound healing, and increased days of hospitalization. This chapter elaborates on early and accurate nutrition screening and assessment as keystones for improving critical outcomes in a vulnerable population. Different validated tools, like NRS-2002, Global Leadership Initiative on Malnutrition (GLIM) criteria, and Nutrition Risk in Critically ill (NUTRIC) score, were developed to guide in identification of the risk of malnutrition. A multidisciplinary approach is emphasized in the implementation of the nutrition care plan; likewise, extended anthropometric, biochemical, and functional assessments are also put to work, along with the prevention of complications, including refeeding syndrome. This comprehensive approach is highly important in developing timely and individualized nutritional interventions that can have a wide impact on the recovery process and minimize morbidity and mortality in critically ill patients.

Keywords: nutrition screening, nutrition assessment, malnutrition, critically ill patients, intensive care

1. Introduction

Critically ill patients are predisposed to an increased risk of malnutrition due to severe medical conditions and physiological stress from illness or injury. Adequate nutrition is a cornerstone in managing such nutritionally depleted states, but maintaining nutrition status in these patients is quite challenging because of the complex, dynamic nature of such critical illness [1]. Malnutrition is a common outcome of hospitalization, particularly in severely ill patients hospitalized in the intensive care unit (ICU) [2]. Between 1996 and 2005, it was found that the prevalence of malnutrition in acute care patients ranged from 13 to 78% [3]. Malnutrition can be caused by both hypermetabolism and a lack of calories and protein in these patients [4]. This chapter discusses the importance of nutrition screening and nutritional assessment in critically ill patients, methods, tools, and strategies for optimization of nutritional care.

Malnutrition is a major concern in patients' disease prognosis; inadequate or excessive food intake, an unbalanced supply of nutrients, or poor nutrient utilization are all considered forms of malnutrition [5]. Improper nutrition is responsible for high rates of illness and death, diminished quality of life, extended reliance on mechanical ventilation, a longer duration of stay in the hospital, and increased healthcare costs. Hence, proper nutrition is crucial for maintaining health and promoting recovery. Adequate nutrition is extremely important for critically ill patients to prevent further disease-related complications. For example, in ICU patients with respiratory failure, emphasis should be placed on proper nutrition to prevent harmful metabolic processes. Effective nutrition can be helpful in boosting the immune system's response [1].

1.1 The pathophysiology of malnutrition in critically ill patients

Critical illness can induce a hypermetabolic and catabolic state to further increase the risk of malnutrition, thus making nutrition screening and nutritional assessment timely and essential [6]. Good nutrition enhances recovery and outcomes in acutely ill patients. Malnourished critically ill patients have increased risk of complications such as immune dysfunction, poor wound healing, infections, and extended hospitalization [5].

Critical illness, which is life-threatening, can result from infection, trauma, or medical conditions. It triggers a large release of proinflammatory mediators and leads to catabolism. This response is the body's way of defending against pathogens and promoting healing. However, an excessive proinflammatory response can be harmful, prompting the body to initiate an anti-inflammatory response. When this balance shifts too far toward an anti-inflammatory state, it can result in immune paralysis, making it harder to fight off pathogens [7]. Thus, a balance between pro- and anti-inflammatory responses is crucial for effective immunity (**Figure 1**). Nutrition is essential in supporting this balance by maintaining muscle mass, decreasing catabolism, and preserving intestinal mucosal integrity and immune function [8].

Malnutrition pathophysiology, as shown in **Figure 1**, can be divided into stress catabolism and decreased nutritional intake. During critical illness, catabolic hormones like glucagon, cortisol, and catecholamines are released to enhance catabolism, mobilizing nutrient reserves and generating glucose, amino acids, and fatty acids to support vital organs [9]. Proinflammatory mediators, such as IL-1, IL-6, and TNF-α, produced during infection or injury, further drive catabolism. The focus during such states is providing proper nutrition to optimize organ function and immune response. ICU patients often have decreased nutritional reserves, and factors like limited food intake during ICU stays, fasting, and obstacles in feeding can lead to underfeeding and aggravating malnutrition [10]. Early recognition and beginning with nutrition can accelerate recovery [11].

The nutritional needs of the patients can be met by following a Nutrition Care Process (NCP) model. NCP is a structured approach to nutrition therapy designed based on the outcomes of a thorough assessment. This plan should be collaboratively formed by a multidisciplinary team, including the patient and their caregiver, to ensure that the treatment is centered on the patient's specific goals. A detailed nutritional care plan outlines the reasoning behind it, describes the nutrition therapy, and guides monitoring its effectiveness and reassessing as needed. NCP includes four aspects: nutrition assessment, nutrition diagnosis, nutrition intervention, monitoring, and evaluation [6].

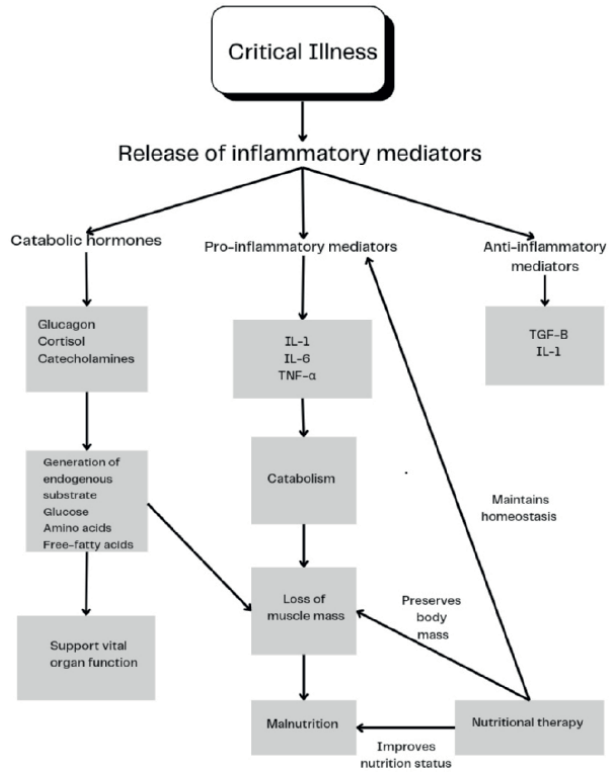

Figure 1.
Pathophysiology of malnutrition. Source: Demling et al. [8].

- Nutrition assessment and reassessment: The goal of nutrition assessment is to gather, correct, and analyze data in order to identify the issues linked to nutrition. It helps in supporting the data in the nutrition diagnosis. It is required if the patient is at nutritional risk [12, 13].

- Nutrition diagnosis: Nutrition information is used to make a nutrition diagnosis. Its goal is to address the problems that could be solved by providing nutrition intervention. This would in turn reduce their hospital stay and further prevent disease-related complications [6]. The PES statement (problem, etiology, signs, and symptoms) is used to make a nutrition diagnosis. For example, for an ICU patient, problems can be muscle atrophy, Etiology: inflammation due to underlying disease, immobilization and hyperglycemia, are signs and symptoms, as evidenced by decreased muscle mass in critically ill patients [13].

- Nutrition intervention: In this step, goals are established, and attention is paid to the steps taken to achieve the desired goals [6]. It has two phases, namely, the planning and the intervention phase. In the planning phase, the dietitian formulates the objectives of the NCP plan in order to achieve the desired outcomes. In the implementation phase, the plan of action is carried out. This step includes food and nutrient delivery, nutrition education, counseling, coordination of care by dietitians, and population-based action [12]. For example, a dietician can plan a tailor-made diet plan according to disease severity for patients with acute respiratory

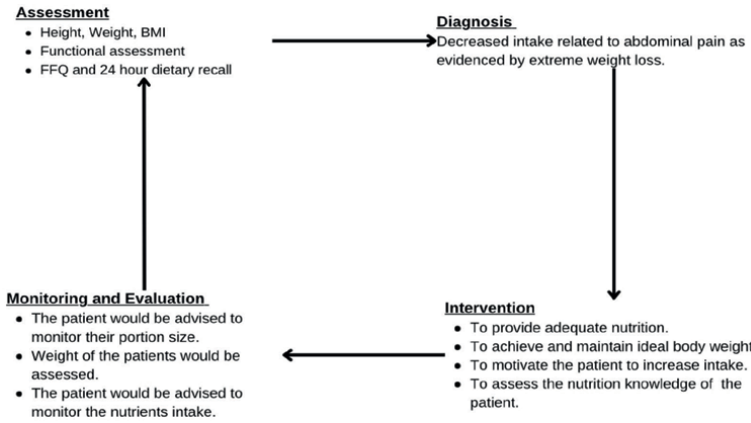

Figure 2.
NCP model of a patient admitted to ICU with colon cancer. Source: Nakanishi et al. [13].

distress (ARDS); a high-protein diet is recommended to increase muscle mass. Blood glucose levels of the patients should also be controlled effectively to prevent muscle atrophy. Hence, high glycemic index foods should not be given [13].

- Monitoring and evaluation: It is the fourth step in the NCP plan. The NCP plan is monitored depending on the nutrition risk. The steps and procedures for monitoring should be prepared well in order to achieve the desired outcomes [1]. It is conducted through biochemical data, anthropometric measurements, and food and nutrition-related histories in clinical settings [14]. In this step, the outcomes are assessed, and a judgment is made about the attainment of short and long-term goals. The reassessment data is further collected to assess the goals of critically ill patients. If desired outcomes are not attained, then the steps and procedures are reevaluated to achieve the goals [6].

- An example of the NCP model of patients with colon cancer is shown in the **Figure 2** where the assessment includes collecting information regarding different anthropometric parameters, functional assessment and dietary analysis followed by assessing the nutritional diagnosis statement which forms the foundation for developing nutrition intervention and monitoring.

2. Importance of nutritional screening and assessment

The nutritional status assessment of critically ill patients tends to deteriorate rapidly after admission due to intense catabolism triggered by stress, proinflammatory cytokines, and hormones, even if the patients were previously well-nourished. Scientific literature indicates that malnutrition occurs in 40–50% of critically ill patients, with 35–50% of all patients at risk of malnutrition. To establish appropriate and individualized nutritional guidelines, it's crucial to conduct a personalized nutritional assessment within the first hours of admission, especially in critical care units. This approach enables the early detection of malnutrition risk and the prompt initiation of suitable nutritional therapy to minimize adverse effects [15].

Nutrition screening and assessment are two methods used to identify individuals at risk and aid in making a nutritional diagnosis. Nutrition screening is generally

intended to be a quicker tool that can be performed by any healthcare professional. However, some screening tools in clinical practice can be quite time-consuming and labor-intensive. On the other hand, nutrition assessment should include factors that not only help establish the nutritional diagnosis but also ensure effective follow-up care for patients after they receive nutritional therapy [16].

The latest guidelines by ASPEN (2018) [17] and ESPEN (2016) [18] underscore the main goal of nutritional assessment is to document key nutritional parameters, identify risk factors and specific nutrient deficiencies, determine nutritional needs, and consider medical, psychosocial, and socioeconomic factors that might impact the prescription and delivery of nutritional support. This involves examining clinical, psychological, social, and nutritional history alongside clinical assessments that measure weight, height, BMI, body composition, biochemical markers, and the requirements for calories, proteins, fluids, and micronutrients.

Nutritional assessment is a structured evaluation of a patient's nutritional status conducted by a trained healthcare professional, typically a dietitian, and it results in a nutrition-related diagnosis [19]. The process begins with a nutritional screening at admission, followed by a more detailed assessment if needed [17]. Unlike nutritional screening, nutritional assessment involves a more extensive collection of information to diagnose malnutrition and assess its severity, while also monitoring changes in nutritional status and the effectiveness of nutritional interventions [16].

Nutritional assessment would be gathering detailed information that can give the specific details of a patient's nutrition status, such as the following:

a. The intake of macronutrients – Includes assessing energy, protein, carbohydrate, and fat, as the critically ill patient may have increased requirements for recovery and preventing muscle wasting.

b. Assessment of micronutrient levels: This includes the deficiencies in vitamins and minerals like vitamin D, vitamin C, zinc, and magnesium, which are required for improving immunity and healing.

c. Anthropometric measurements: Follow the variation of body weight, BMI, and muscle mass that may indicate weight loss or even malnutrition.

d. Biochemical data: It includes laboratory tests, which follow the serum protein, electrolytes, glucose, and inflammatory markers like CRP to follow the profile of malnutrition along with inflammation.

e. Functional status: Measures strength and mobility for following physical decline caused by malnutrition.

f. Dietary history: Follows the patient's typical intake and dietary restrictions as a customized approach.

g. Determination of the gastrointestinal function: Any possible existence of a digestive problem or impairment in the absorptive function which might warrant special nutrition support.

This assessment could be used in identifying malnutrition, monitoring the patient's progression, and guiding the interventions for recovery.

Nutrition screening on the other hand is "a method to identify individuals who are malnourished or at risk for malnutrition to decide if a complete nutrition assessment

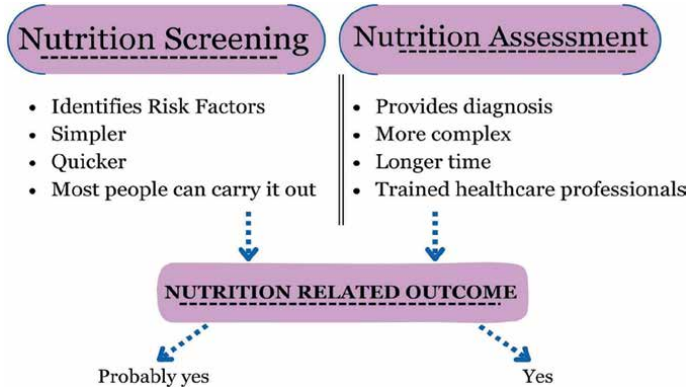

Figure 3.
Difference between nutrition screening & nutrition assessment. Source: Correia [16].

is needed," according to the ASPEN (2018) [17]. A comparable definition is provided by the European Society for Clinical Nutrition and Metabolism [18]. Patients at nutritional risk should be identified through a validated screening process and periodically re-screened according to institutional policies or standards.

A systematic review by Domenech-Briz et al. found that assessing nutritional risk in critically ill patients has beneficial effects, such as improving patient prognosis with individualized nutritional therapy, identifying patients at higher risk of morbidity and mortality who might benefit from nutritional support, and better matching the energy needs of ICU patients [15]. **Figure 3** shows the difference between nutrition screening and nutrition assessment.

3. Nutrition screening: Finding the patients at risk of malnutrition

Nutrition screening identifies patients at risk of malnutrition. ESPEN (2017) defines nutrition risk as the potential for better or worse outcomes based on one's nutritional and metabolic status, though there is no universal definition for this screening. It is recommended that screening be conducted within 24–48 hours of ICU admission, using tools that vary in strengths and weaknesses [18]. Effective tools should be user-friendly, quick, cost-effective, standardized, and validated. They must be sensitive, specific, and able to predict nutritional therapy success. A clinical protocol should follow positive results [20].

Several key considerations must be taken while implementing nutrition screening:

a. Selection of screening tools: Preferred tools include the Nutritional Risk Screening 2002 (NRS-2002) and the Malnutrition Universal Screening Tool (MUST). Since no single tool is perfect, different ones are applied depending on the clinical setting and patient population.

b. The tool should be user-friendly so that healthcare staff can perform the screening easily and with no additional burden on the already congested workload.

c. Efficiency and cost-effectiveness: A very practical screening tool is one which can be completed in a few minutes and with the least possible resource requirements with no specialist skill.

d. Standardization and validation: The screening tool shall be validated for various populations and integrated into standardized practice so that cases are identified uniformly.

e. Sensitivity and specificity: It must be sensitive enough to pick up the risk cases and simultaneously highly specific to minimize false positives. Poorly sensitive or poorly specific tools will delay appropriate nutritional interventions or engender unwarranted treatments.

f. Protocol for positive results: If results are positive, a positive screening result should trigger a clinically constructed protocol designed to include comprehensive nutrition assessment, individualized nutrition therapy, and follow-up to monitor response.

g. This is a multidisciplinary approach that includes dietitians, nurses, and physicians in order to ensure effective implementation.

h. Reassessment: Patients in the ICU must be reassessed frequently since their clinical condition as well as the nutritional needs change quickly during their stay.

This essentially means early identification of at-risk malnutrition by doing structured and practical nutrition screening with clinicians, with timely, effective nutritional interventions.

Reviews on the validity and reliability of screening tools suggest that multiple methods should be used to assess nutritional status, as no single tool is sufficiently reliable for all situations [21–23]. Various nutrition screening tools are used globally, including mNUTRIC, NRS 2002, NUTRIC, MUST etc. These tools generally take into account elements like:

- *Medical history*: Including age, comorbidities, and loss of physical function.
- *Nutrition history*: Covering aspects like weight loss, reduced food intake, and loss of appetite.
- *Physical examination*: Considering BMI, edema, and body composition.
- *Severity of illness*: Realizing that patients who are critically ill.

Metrics like BMI and weight history are frequently challenging among critically ill patients. It requires weighing patients, which can be difficult for critically ill patients. Furthermore, variations in volume status might influence weight assessments and make clinical tests more difficult, such as anthropometry. Every patient in the ICU for longer than 48 hours is deemed to be at nutritional risk according to the ESPEN (2019) guideline [24]. The German Society for Nutritional Medicine (DGEM) guideline recommends considering factors like low BMI, unintended weight loss, and lack of oral food intake, or using the Subjective Global Assessment (SGA) for critically ill patients. Although technical tools such as CT scans, musculoskeletal ultrasound, and bioelectrical impedance analysis (BIA) are available for assessing and monitoring nutritional status in the ICU, they are not yet widely implemented in routine clinical practice. Therefore, no single "gold standard" exists for diagnosing malnutrition, but many helpful tools and criteria are available, and all ICU patients should be regularly screened for malnutrition risk [25].

Following are the nutrition screening tools that are widely used across the globe for nutritional screening of patients in a hospital setting:

3.1 Nutritional risk screening (NRS-2002)

The NRS-2002 is extensively utilized in critically ill patients and is designed to assess both nutritional status and disease severity to identify those at risk. It serves as a general tool within hospital settings to pinpoint patients who would benefit from nutritional interventions [26]. The NRS-2002 is a simple yet rigorously tested instrument that begins with a pre-screening consisting of four questions. If any of these questions are answered positively, a more detailed screening follows. This process includes evaluating nutritional status through surrogate measures, along with assessing both static and dynamic parameters and the severity of the disease (stress metabolism). Each parameter can score between 0 and 3 points. Being over 70 years old is considered a risk factor and adds one point in the screening tool. A total score below three indicates that the patient is either malnourished or at risk of malnutrition, suggesting the need for nutritional therapy. The NRS-2002 has been extensively validated through numerous studies, including randomized controlled trials, and has consistently shown high reliability when used by trained personnel [21]. A systematic review by Domenech-Briz et al. [15] identified the NRS-2002 as the second most frequently used tool, with consistent application observed across studies. The template for the NRS-2002 tool is given in the following **Table 1**.

Final screening			
Impaired nutritional status		**Severity of disease (increased requirements)**	
Absent **Score 0**	Normal nutritional requirements	Absent **Score 0**	Normal nutritional requirements
Mild **Score 1**	Weight loss >5% in 3 months, or food intake below 50–75% of normal requirement in preceding week	Mild **Score 1**	Hip fracture,* chronic patients, in particular, with acute complications: *cirrhosis,* COPD,* chronic hemodialysis, diabetes, oncology*
Moderate **Score 2**	Weight loss >5% in 2 months, or BMI 18.5–20.5 + impaired general condition, or food intake of 20–60% of normal requirement in the preceding week	Moderate **Score 2**	Major abdominal surgery, * stroke,* *severe pneumonia, hematologic malignancy*
Severe **Score 3**	Weight loss >5% in 1 month (> 15% in 3 months), or BMI < 18.5 + impaired general condition, or food intake of 0–25% of normal requirement in preceding week	Severe **Score 3**	Head injury, * bone marrow transplantation,* *intensive care patients (APACHE > 10)*
Score: + Score: = Total score:			
Age if ≥7 – years: add 1 to the total score above = **Age-adjusted total score**			
Score ≥ 3: the patient is nutritionally at risk, and a nutritional care plan is initiated. **Score < 3:** Weekly rescreening of the patient. If the patient, for example, is scheduled for a major operation, a preventive nutritional care plan is considered to avoid the associated risk status.			
Source: Serón-Arbeloa et al. [21].			

Table 1.
Nutrition risk screening (NRS-2002).

3.2 Malnutrition universal screening tool (MUST)

The Malnutrition Universal Screening Tool (MUST) was developed by the British Association for Parenteral and Enteral Nutrition (BAPEN) [27]. It is mainly used in the general population, though it may also be adapted for ICU use. However, it might be less sensitive for critically ill patients. It categorizes patients according to the risk of malnutrition based on BMI, the presence of involuntary weight loss, and the potential for future weight loss due to acute illness, considering the absence of food intake for more than 5 days. Each factor is scored from 0 to 2 points for BMI, weight loss, acute illness related to food intake over the next 5 days. MUST is widely used for all types of hospitalized patients, and ESPEN (2016) recommends its use at the community level [18]. Its reliability is similar to that of the Mini Nutritional Assessment (MNA) in screening for nutritional risk in elderly populations. MUST can predict hospital stay length, the possibility of discharge to other hospitals or long-term care centers, the likelihood of readmission, and it can track progress after the start of nutritional intervention. It is known for being fast and reproducible [21].

However, MUST is not validated for use in the ICU. A study by MAjari et al. [28] found no association between high MUST scores and longer ICU stays, prolonged mechanical ventilation, or 28-day mortality. Similarly, a cross-sectional study of 251 surgical ICU patients revealed no significant correlation between MUST and ICU length of stay, duration of mechanical ventilation, or mortality [29]. Comparable findings were observed in a Dutch ICU population, indicating that MUST is not a good predictor of 28-day mortality or prolonged mechanical ventilation (>2 days) in critically ill patients [30]. The template for Malnutrition Screening Tool is given in the following **Figure 4**.

3.3 The nutrition risk in critically ill (NUTRIC) score

In 2011, a new scoring system was introduced, the Nutrition Risk in Critically Ill (NUTRIC), which was specifically designed for ICU patients. It has gained wide

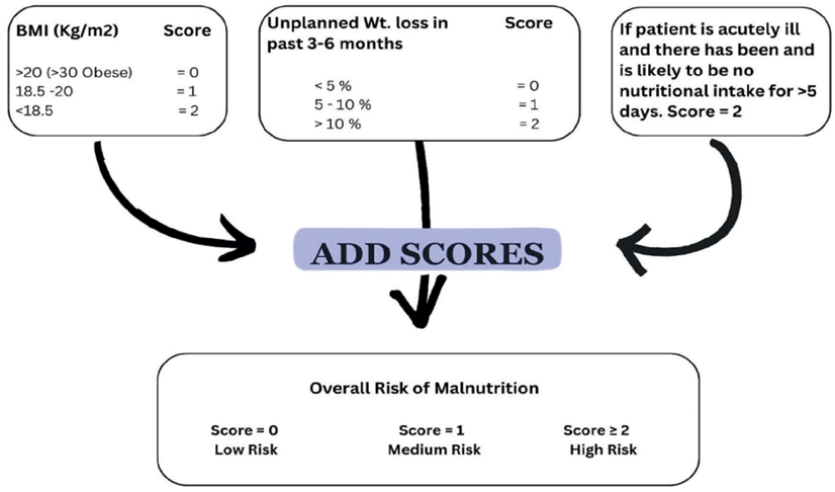

Figure 4.
Malnutrition universal screening tool. Source: Elia [27].

acceptance as a simple and reliable tool to screen critical patients. The NUTRIC score includes six variables, most of which are easily obtainable in ICU settings [31]. The NUTRIC score includes both nutritional and non-nutritional factors as predictors. While many other risk scores and assessment tools exist to evaluate nutritional risk, none were specifically developed for ICU patients until the NUTRIC score. Most general assessments assume all critically ill patients are at high nutritional risk, but the NUTRIC score recognizes that not all ICU patients will respond equally to nutritional interventions [32]. The NUTRIC score helps to identify which ICU patients would benefit most (or least) from aggressive nutritional therapy, making it the first nutritional risk assessment tool validated specifically for ICU patients.

Unlike other nutritional screening methods that are often seen as cumbersome and time-consuming, and thus not routinely used, the NUTRIC score is practical, relying on variables that are easy to gather in a critical care setting [31]. It predicts mortality in critically ill patients by classifying them into low or high nutritional risk based on factors such as age, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, Sequential Organ Failure Assessment (SOFA) score, number of comorbidities, duration of hospitalization before ICU admission, and CRP levels. Patients with high NUTRIC scores are at greater risk of death within 28 days. The NUTRIC score has shown excellent alignment with CRP levels and high predictive validity in assessing

NUTRIC Score variables

Variable	Range	Points
Age	<50	0
	50 - <75	1
	≥75	2
APACHE II	<15	0
	15 - <20	1
	20-28	2
	≥28	3
SOFA	<6	0
	6 - <10	1
	≥10	2
Number of Co-morbidities	0-1	0
	≥2	1
Days from hospital to ICU admission	0 - <1	0
	≥1	1
IL-6	0 - <400	0
	≥ 400	1

NUTRIC Score scoring system: if IL-6 available

Sum of points	Category	Explanation
6-10	High Score	➢ Associated with worse clinical outcomes (mortality, ventilation). ➢ These patients are the most likely to benefit from aggressive nutrition therapy.
0-5	Low Score	➢ These patients have a low malnutrition risk.

NUTRIC Score scoring system: If no IL-6 available*

Sum of points	Category	Explanation
5-9	High Score	➢ Associated with worse clinical outcomes (mortality, ventilation). ➢ These patients are the most likely to benefit from aggressive nutrition therapy.
0-4	Low Score	➢ These patients have a low malnutrition risk.

*It is acceptable to not include IL-6 data when it is not routinely available; it was shown to contribute very little to the overall prediction of the NUTRIC score.

Figure 5.
NUTRIC score. Source: Heyland et al. [31].

mortality risk. When combined with the SGA for diagnosing malnutrition, the NUTRIC score's accuracy in predicting mortality improves further. This combination is particularly valuable for clinical decision-making and patient management in intensive care settings [33].

The NUTRIC score is easy to calculate, as it includes variables that are available for the patients in the hospital setting, except for IL-6 levels, which are not commonly assessed. In practice, many ICUs use the NUTRIC score without the IL-6 level, raising questions about its validity in such cases (modified NUTRIC score). In 2015, Rehman et al. provided independent validation of the NUTRIC score without IL-6 levels, demonstrating its effectiveness in identifying which ICU patients would benefit from early, tailored protein-energy provision [32]. The template for Nutric Score is given in **Figure 5**.

3.4 The perioperative nutrition screen (PONS)

A preoperative tool designed to identify patients at risk of malnutrition aims to guide appropriate nutritional interventions throughout the perioperative period. Improved programs for perioperative optimization are essential to address the often undiagnosed and inadequately managed issue of perioperative malnutrition, which adversely affects surgical outcomes. Malnutrition is known to increase the risk of perioperative death by five times and complications by three times in major elective surgeries [34]. Therefore, proactive preoperative nutrition assessment and intervention should become standard practice for major elective procedures due to its multiple benefits.

While there are existing tools to assess malnutrition in hospitalized patients, no specific tools have been developed to identify preoperative malnutrition and guide perioperative nutritional care. To address this gap, the Perioperative Nutrition Screen (PONS) was created on previously validated criteria from the MUST but tailored for preoperative patients. It assesses nutritional risk using four criteria: BMI < 18.5 for patients aged 65 or younger, or BMI < 20 for patients older than 65; unintentional

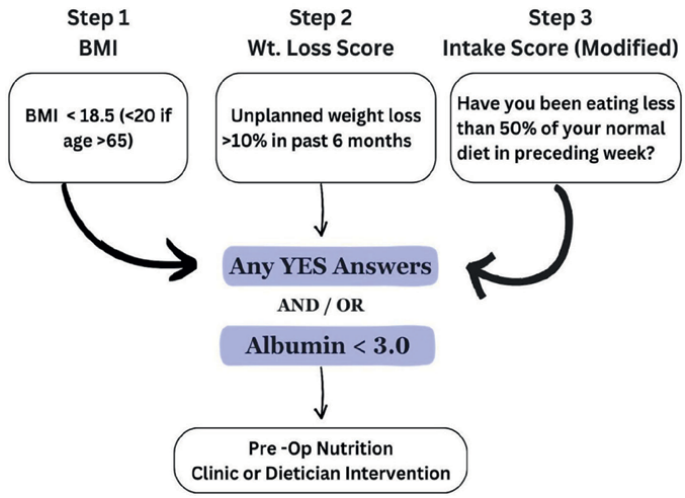

Figure 6.
Preoperative nutrition screen. Source: Wischmeyer et al. [35].

weight loss greater than 10% over the last 6 months; less than 50% of normal oral intake in the past week; or a serum albumin level below 3 g/L. Each criterion in the PONS tool is assigned one point for a positive response, with a maximum score of 4 (**Figure 6**). A PONS score of 1 or higher indicates a high risk for perioperative malnutrition, prompting referral for further evaluation and management [34, 35].

3.5 Nutrition screening tools for malnutrition in hospital settings

Table 2 provides a concise overview of nutrition screening tools commonly used to assess malnutrition risk in hospital settings, including critically ill patients. Each tool is evaluated based on its core setting, advantages, disadvantages, and key components, offering insights into its practical applications and limitations in clinical environments. The choice of appropriate screening tools would again depend on the population of patients, the resources available, and the expertise of the healthcare team. The aim again is to have a tool to quickly identify those patients who would need further nutritional assessment and intervention. **Table 2** shows the components of different screening tools used for malnutrition screening in hospital settings for patients including critically ill patients [15].

Features	mNUTRIC	NUTRIC	NRS-2000	MUST	PONS
Age	X	X	X		
APACHE	X	X			
SOFA	X	X			
Comorbidities	X	X			
Days of hospital admission	X	X			
IL-6		X			
IMC			X	X	
Percentage of weight loss			X	X	X
Energy intake Compared to energy needs			X		X
Severity of illness			X	X	
Ener				X	
Muscle loss					
Metabolic stress					
Physical examination					
Nutritional risk classification	<to 3: low risk ≥to 4: high risk ≥5: high risk	≤to 5: low risk ≥to 6: high risk	<to 3: low risk 3: risk to 5: high risk	0: low risk 1: medium risk ≥to 2: high risk	≥ 1: high risk for perioperative malnutrition

Source: Domenech-Briz et al. [15].

Table 2.
Components of different screening tools.

Screening tool	Tool components	Advantages	Disadvantages
NRS-2000 • Hospital	• Weight loss • Food intake • BMI • Disease severity	• Content & predictive validity • Moderately reliable • Practical • Considers disease severity	Weight from fluid collections (ascites, peripheral edema) not accounted
MUST • Community	• BMI • Unable to eat for ≥5 days • Unplanned weight loss in past 3–6 months • Acutely ill	• High inter-rater reliability • Content & predictive validity for length of hospital stay & mortality • Practical	• Weight from fluid collections (ascites, peripheral edema) not accounted • Disease severity not considered
NUTRIC Score • Critically Ill	• Age • APACHE II & SOFA scores • Comorbidities • Days in hospital pre-ICU • Interleukin-6	• Externally validated (n = >1000pts)	• Interleukin-6 not widely available • Requires training • Classic nutrition parameters not considered
PONS • Pre-Operative	• BMI • Weight loss • Food Intake • Albumin Level	Simple to use and easy to interpret	• Not highly validated for critically ill patients.

Source: Tandon et al. [36].

Table 3.
Summary of nutrition screening tools.

Table 3 shows the summary of nutrition screening tools used for malnutrition screening in hospital settings for patients including critically ill patients. Considering the challenges in using these popular tools it is crucial to validate and modify these according to the disease and its severity. Irrespective of the disadvantages and challenges, the crucial need to assess nutritional risk cannot be overlooked (**Table 3**).

4. Nutritional assessment tools and strategy

After assessing the patient's nutritional risk, it is imperative to analyze the grade/level of malnutrition. A systematic approach is crucial since no single test can fully assess nutritional status. Instead, a methodical gathering of information is necessary, with nutritional status evaluated based on the collected data [37]. Various methods have been developed over time for nutritional assessment, ranging from complex, costly techniques used in research to more accessible methods suitable for routine clinical practice. The ideal method should be both sensitive and specific enough to accurately diagnose nutritional status, predict outcomes,

and reflect changes in an individual's nutritional condition [16]. A thorough nutritional assessment typically includes four main components, known as the "ABCD" approach: Anthropometry, Biochemical, Clinical, and Dietary evaluations. Such an assessment would involve a careful review of the nutritional status of the patient, including:

4.1 Anthropometric measurements

Anthropometry, derived from the Greek words "anthropos" (human) and "metron" (measure), involves the systematic measurement and analysis of human body dimensions, including body weight, size, and shape [38]. This method offers a portable, cost-effective, and non-invasive way to assess body size, proportions, and composition [21].

Height, weight, BMI, body circumferences, and body composition are some of the common measurements used in anthropometry (**Figure 7**). For critically ill patients, bed scales and chair scales are alternatives for assessing weight. Also, height can be taken using alternative measurements like arm span and knee length [42]. BMI can be computed using height and weight obtained through alternative methods. Body circumference and arm fold thickness can also be assessed. These parameters may, however, be difficult to obtain or unreliable in critically ill patients due to fluid shifts and edema.

Since most of these parameters are not reliable and valid for the assessment of critically ill patients, assessment of body composition using advanced techniques should be taken into consideration [43, 44]. Although accurate and non-invasive, these methods may not be ideal for clinical settings due to their expense and time consumption [21, 44]. However, muscle ultrasonography can be used as it is radiation-free, portable, and allows for bedside estimations of muscle mass [45]. Muscle ultrasonography measures the thickness of subcutaneous fat and the area of specific muscles, particularly the anterior quadriceps rectus, which is useful in identifying muscle loss due to malnutrition and catabolism, and in tracking improvements during re-nutrition [46].

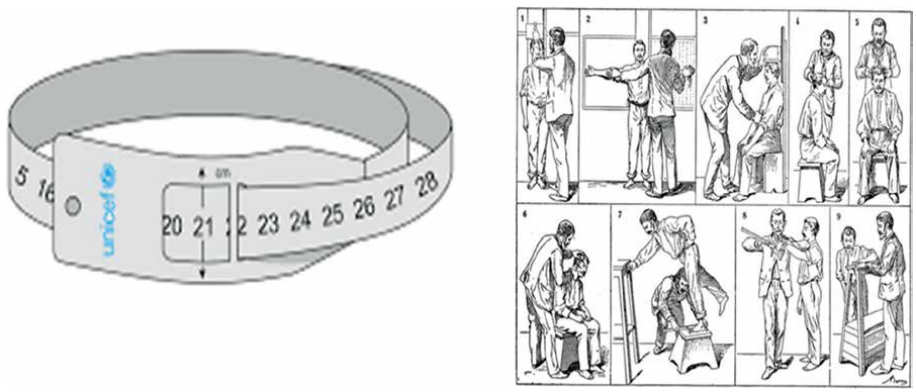

Figure 7.
Anthropometric measurements. Source: Unicef.org; Caballero [39–41].

4.2 Biochemical data

No single parameter can comprehensively assess nutritional status or monitor nutritional therapy. However, routine clinical laboratory parameters such as complete blood count, lipid profile, electrolytes, and liver function tests can provide valuable insights into a patient's nutritional state. These parameters help detect nutrient deficiencies, understand the etiology of malnutrition, and monitor nutritional therapy progress. They also offer information on disease severity and activity, as well as changes in body composition [20].

In patients with chronic malnutrition, laboratory values can identify deficiencies in vitamins and trace elements. This information is critical for monitoring ongoing supplementation therapies. During the initial refeeding phase, deficiencies in potassium, phosphate, and magnesium can lead to severe complications like refeeding syndrome, necessitating close monitoring of these electrolytes [20].

Traditionally, serum visceral proteins such as albumin and prealbumin have been used to assess nutritional status. Prealbumin is often preferred due to its shorter half-life, which reflects more rapid changes in nutritional status. However, these proteins are heavily influenced by inflammation, which inhibits visceral protein synthesis. Consequently, their use as nutritional biomarkers is debated. Current consensus suggests that these laboratory markers should complement a thorough physical examination [47].

Other potential markers of nutritional status, such as urinary creatinine or 3-methylhistidine (indicators of muscle protein breakdown), have not gained widespread use. However, as readily quantifiable indicators of surgical outcomes and death in severe conditions, biomarkers such as prealbumin may still be of importance [47]. Thus, it can be said that albumin, prealbumin and CRP give information about the current nutritional and inflammation status of the patient though they are influenced by factors other than nutrition.

4.3 Clinical history and physical examination

A patient's clinical history offers a subjective and retrospective overview of their condition, serving as the starting point for nutritional assessment. This involves discussing factors contributing to malnutrition, such as pain, gastrointestinal issues (e.g., diarrhea, vomiting, constipation), weight loss, appetite loss, difficulties in chewing or swallowing, and poor oral health. The clinical history should also encompass any previous medical conditions (chronic or acute diseases, psychiatric symptoms, conditions that may lead to metabolic stress such as infections), as well as the patient's current functional capacity and physiological changes that might affect nutritional needs or body composition, such as muscle mass loss [20]. **Figure 8** shows the clinical signs and symptoms of a chronic liver disease patient. For critically ill patients this information can be collected from the family members or the patient if he/she is not in a condition to provide such information.

The physical examination focuses on identifying signs of muscle atrophy, loss of subcutaneous fat, hydration status, and other indicators of specific nutritional deficiencies. A "nutrition-focused physical examination" (NFPE) is often used, which involves a comprehensive physical exam to detect malnutrition-related alterations in muscle mass, subcutaneous fat, hair, skin, eyes, oral cavity, nails, edema, ascites, and overall appearance [49, 50]. This examination follows a head-to-toe approach [51].

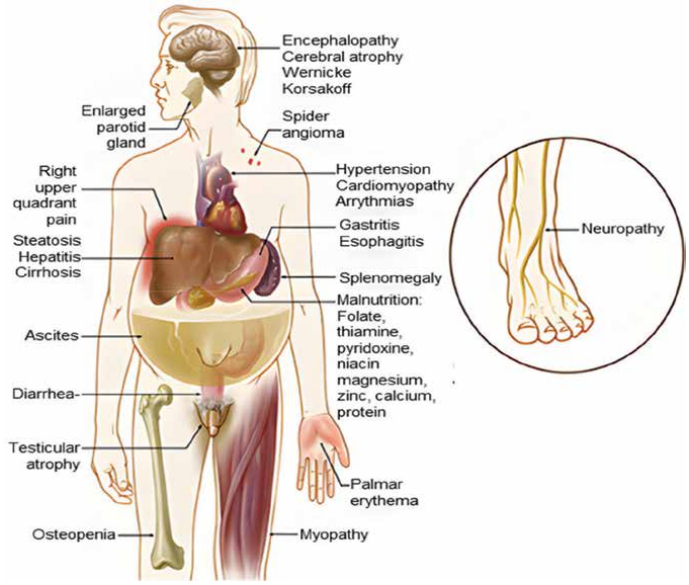

Figure 8.
Clinical signs & symptoms of a chronic liver disease patient. Source: Krause & Mahan [48].

In critical illness, various medical interventions, such as lines, tubing, and other devices, can complicate an NFPE. A bedridden patient's position can influence muscle and fat distribution. For instance, if one shoulder is consistently raised, that side may exhibit clavicular muscle wasting, while the other side may not. Equipment like EEG electrodes, endotracheal tubes with restraining straps, central lines, catheters, and devices like pacemakers or ventricular assist devices inserted in the neck, chest, or shoulders, can also interfere with NFPE. Additionally, items like blood pressure cuffs, mitts, hand restraints, abdominal binders, wound dressings, cooling pads, and compression stockings may obscure accurate assessment. Fluid overload and sedation further complicate evaluations, as some critically ill patients may experience significant fluid retention throughout the body, limiting the ability to assess muscle mass and fat reserves effectively [51].

4.4 Dietary assessment

It assesses usual dietary intake, nutritional needs, and difficulties of receiving nutrition that include mechanical ventilation and gastrointestinal dysfunction. Assessing nutritional risk begins with a thorough nutritional history. In critically ill patients, indirect information about the patient's nutrition intake may be obtained from nursing. It involves assessment of nutrient intake from oral, enteral and parenteral routes of feeding. Information such as unintentional weight loss over the last 3–6 months and recent decreases in nutrient intake, gathered from family members, can be useful in understanding the patient's nutritional history [52].

Quantifying food intake is a crucial aspect of assessing nutritional risk in individual patients. This entails assessing micronutrients (vitamins, trace elements) as well as macronutrients (fats, carbohydrates, proteins). Various standardized methods are available for measuring food intake, including 24-hour food recalls, food frequency questionnaires, and direct observation (food records are often used by nurses

for institutionalized patients). Though daily patient intake record through 24-hour dietary recall is considered more practical for critically ill patients. These methods provide semi-quantitative information, but accurately assessing food intake is challenging and prone to errors. There is a growing demand for more precise dietary assessment methods [53].

4.5 Functional assessment

Given that quality of life is directly impacted by muscle strength and cognitive function, functional tests are becoming more and more significant in the evaluation of nutritional status. Energy deficiency reduce muscle strength, power, and overall physical condition [20]. Muscle strength and function are particularly important in conditions like sarcopenia, cachexia, and frailty, seen in critically ill patients, making the assessment of muscle strength a crucial part of evaluating patients suspected of having sarcopenia [54].

Serial dynamometry, which measures handgrip strength, is a reliable method for monitoring functional progress. Hand dynamometry is recognized as a valid nutritional marker, correlating well with nutritional status and predicting surgical outcomes, length of hospital stays, re-hospitalization rates, and overall physical condition. It also serves as a good predictor of both short- and long-term mortality [55, 56]. But most critically ill patients are unable to perform a handgrip strength test; this is at least partly due to the sedation used in critical illness or due to an altered mental status [47].

Additionally, respiratory function can also be used for functional assessment which can be assessed using peak flow and FEV1 (forced expiratory volume) measurements to evaluate respiratory muscle strength. Immune function can be gauged by measuring the cellular response to intradermal antigens, as severe malnutrition can result in energy depletion and reduced protein reserves [21]. Following **Table 4** summaries the nutrition assessment methods for critically Ill patients.

4.6 Tools used for clinical assessment

Nutritional evaluation is a formal assessment of a patient's nutritional state performed by a trained healthcare practitioner, typically a dietician, that leads to a nutrition-related diagnosis. Once a patient has been recognized as at risk using the screening measures above, a nutritional assessment should be conducted. The following are the tools that are commonly used across the globe for nutritional assessment in clinical or hospital settings.

4.6.1 Subjective global assessment

The Subjective Global Assessment (SGA), created in 1982, is a validated method for assessing nutritional status that not only diagnoses malnutrition but also offers crucial prognostic information across various patient groups. It helps identify patients who may benefit from nutritional intervention, potentially reducing the risks of morbidity and mortality associated with nutrition-related complications [57]. The SGA evaluates nutritional status by examining patient history (including weight change, dietary intake, gastrointestinal symptoms, functional capacity, and the disease's impact on nutritional needs) and physical examination (evaluating the existence of edema or ascites, muscle atrophy, and loss of subcutaneous fat). Patients are then

Assessment method	Assessment tool	Challenges faced in critically ill patients	Alternative for bedridden ICU patients
Anthropometry	Weight	Weighing is not feasible using electronic weighing scales if the patient is unconscious or unable to stand. Also, fluid retention makes weight unreliable in critically ill patients.	Bed scales or chair sales can be used for critically ill patients [7].
	Height	Like weight, taking height is also not feasible for critically ill patients who might be unconscious or unable to stand.	For height, arm span and knee length can be used in critically ill patients [7].
	BMI	For BMI, height and weight of the patient is required, which are difficult to obtain in a critically ill patient. Similar to weight, BMI is also not very reliable in critically ill due to fluid retention. It also is not helpful in the diagnosis of sarcopenia.	Once height and weight are obtained using alternative methods then BMI can be computed for the critically ill. Since it is not very reliable in critically ill patients, body composition should be assessed.
	Body Composition	MAC and TSF is not a reliable method in patients with fluid overload. BIA is not recommended in patients with fluid overload, in intensive care unit patients, or in the elderly. Other advanced techniques like DEXA, CT Scan and MRI are accurate but are non-invasive, expensive, time-consuming and are not ideal for patients in critical care.	Ultrasonography can be used as the equipment is portable and muscle mass can be estimated at the bedside [45].
Biochemical Assessment	Different parameters like albumin, prealbumin, transferrin, creatinine, lymphocytes, IGF-1 etc. are assessed in Biochemical assessment.	No single parameter can be used for assessing nutritional status. These parameters are affected by factors like inflammation.	Laboratory markers should complement a thorough physical examination [47].
Clinical Assessment	Clinical History.	Since the patient in critical care might be sedated or unconscious it is difficult to obtain clinical history.	Such information can be obtained from the family members/ nursing attendant of the patient.
	Physical examination	Critical illness with its lines, tubing and other devices can skew NFPE	—
	Functional Assessment	Most critically ill patients are unable to perform hand grip strength tests	—

Assessment method	Assessment tool	Challenges faced in critically ill patients	Alternative for bedridden ICU patients
Dietary Assessment	There are various methods to assess diet like 24-Hour Recall, Food Frequency Questionnaire, Food Records etc.	All these methods are difficult to administer on critically ill patients due to sedation used in critical illness or due to altered mental status.	Food records can be used by nurses to assess the dietary intake of critically ill patients. Diet history and other related information can be gathered from family members [48].

Table 4.
Nutritional assessment of critically ill patients.

categorized as well-nourished (A), moderately malnourished or at risk of malnutrition (B), or severely malnourished (C) [58]. This classification assists clinicians and dietitians in grading the severity of malnutrition and setting nutritional goals accordingly. The template for Subjective Global Assessment is given in the following **Figure 9**.

Previous studies have supported the growing evidence that SGA is a viable assessment method for critically ill patients and may correlate with clinical outcomes like

SUBJECTIVE GLOBAL ASSESSMENT RATING FORM

Patient Name: **ID #:** **Date:**

HISTORY

WEIGHT/WEIGHT CHANGE: ***(Included in K/DOQI SGA)*** — **Rate 1-7**

1. **Baseline Wt:** _____(Dry weight from 6 months ago)
   Current Wt: _____(Dry weight today)
   Actual Wt loss/past 6 mo: _____ **% loss:**_____(actual loss from baseline or last SGA)
2. **Weight change over past two weeks:** _____No change _____Increase _____Decrease

DIETARY INTAKE No Change_____(Adequate) No Change_____(Inadequate)

1. Change: Sub optimal Intake: _____ Protein _____ Kcal _____ Duration_____
   Full Liquid: _____ Hypocaloric Liquid _____ Starvation _____

GASTROINTESTINAL SYMPTOMS ***(Included in K/DOQI SGA-anorexia or causes of anorexia)***

Symptom:	Frequency:*	Duration:+
_____ None	_____	_____
_____ Anorexia	_____	_____
_____ Nausea	_____	_____
_____ Vomiting	_____	_____
_____ Diarrhea	_____	_____
	Never, daily, 2-3 times/wk, 1-2 times/wk	> 2 weeks, < 2 weeks

FUNCTIONAL CAPACITY — b

Description	Duration:
_____ No Dysfunction	_____
_____ Change in function	_____
_____ Difficulty with ambulation	_____
_____ Difficulty with activity (Patient specific "normal")	_____
_____ Light activity	_____
_____ Bed/chair ridden with little or no activity	_____
_____ Improvement in function	_____

DISEASE STATE/COMORBIDITIES AS RELATED TO NUTRITIONAL NEEDS

Primary Diagnosis_____Comorbidities_____
Normal requirements ____Increased requirements____ Decreased requirements _____
Acute Metabolic Stress: _____None _____Low _____Moderate _____High

PHYSICAL EXAM

_____ Loss of subcutaneous fat (Below eye, triceps, biceps, chest) ***(Included in K/DOQI SGA)*** ____Some areas _____All areas
_____ Muscle wasting (Temple, clavicle, scapula, ribs, quadriceps, calf, knee, interosseous ***(Included in K/DOQI SGA)*** ____Some areas _____All areas
_____ Edema (Related to undernutrition/use to evaluate weight change)

OVERALL SGA RATING

Very mild risk to well-nourished=6 or 7 most categories or significant, continued improvement.
Mild-moderate = 3, 4, or 5 ratings. No clear sign of normal status or severe malnutrition.
Severely Malnourished = 1 or 2 ratings in most categories/significant physical signs of malnutrition.

Figure 9.
Subjective global assessment. Source: Detsky et al. [58].

mortality rates. It has been well established that traditional nutritional markers, anthropometric measurements, and biochemical data are unreliable in critically ill populations. Given that the SGA is a simple, feasible, cost-effective, and non-invasive nutritional assessment tool that can be performed at the patient's bedside, it is recommended for routine use in critically ill patients [59, 60].

4.6.2 GLIM criteria

Malnutrition is a major issue linked to increasing rates of morbidity, mortality, and healthcare costs. However, there has been a significant lack of agreement on diagnostic criteria for clinical use, and no single method has gained global acceptance. To address the needs of the clinical nutrition and medical communities, the Global Leadership Initiative on Malnutrition (GLIM) was established in January 2016. GLIM brought together several international clinical nutrition organizations, such as the ASPEN, ESPEN, the Parenteral and Enteral Nutrition Society of Asia (PENSA), and the Latin American Federation of Nutritional Therapy, Clinical Nutrition, and Metabolism (FELANPE), to work on standardizing the diagnosis of malnutrition in clinical practice [54].

The criteria considered for diagnosing malnutrition were drawn from existing methods of screening and assessment. The consensus strongly supported the selected core phenotypic and etiologic criteria, which are already widely used across the globe. This criterion can be easily integrated with other diagnostic methods and regional preferences, their global adoption is more feasible. The consensus criteria were designed to be simple and easily implemented by clinicians and other healthcare professionals using commonly available tools and methods, requiring only minimal training. The proposed approach includes both risk screening and diagnosis, though it does not provide the detailed information of a comprehensive nutritional assessment [54].

The top five criteria identified include three phenotypic criteria (unintentional weight loss, low body mass index, and reduced muscle mass) and two etiologic criteria (decreased food intake or absorption, and the presence of inflammation or disease burden). A diagnosis of malnutrition requires at least one phenotypic and one etiologic criterion. The phenotypic criteria can be used to grade malnutrition severity into Stage 1 (moderate) and Stage 2 (severe). It is recommended that the etiologic criteria guide interventions and predict outcomes. This approach supports the classification of malnutrition into four categories based on etiology (**Table 5**) [54].

4.6.3 Royal free hospital nutrition prioritizing tool (RFH-NPT)

The Royal Free Hospital Nutrition Prioritizing Tool (RFH-NPT) was initially developed through a multicenter study in the UK to assess nutritional status in patients with chronic liver disease. It is designed to be simple to use in clinical settings, allowing even non-specialist staff to effectively utilize the tool, which helps

Phenotypic criteria			**Etiological criteria**	
Unintentional weight loss	Low body mass index	Reduction of muscle mass	Decreased intake or assimilation of foods	Inflammation

Table 5.
GLIM criteria of etiological and phenotypic patient characteristics.

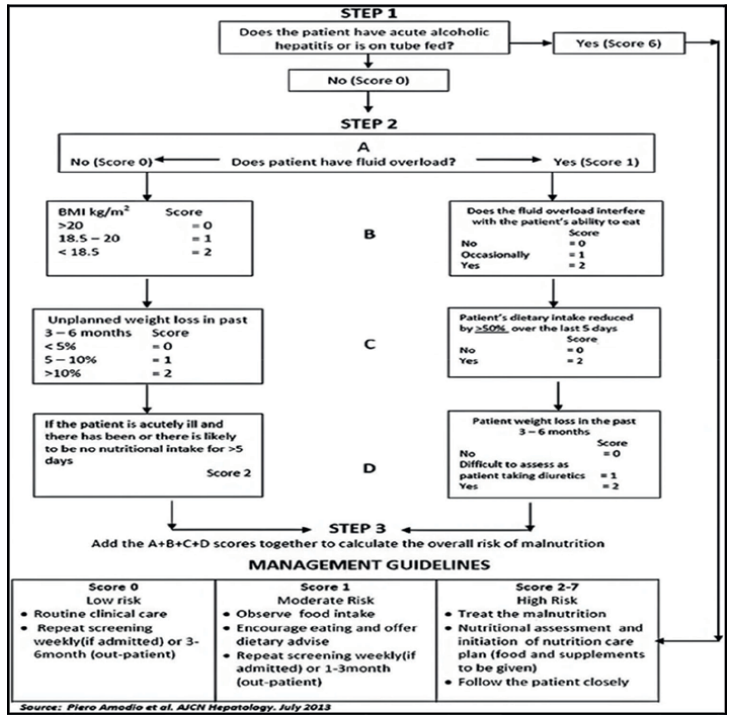

Figure 10.
Royal free hospital nutrition prioritizing tool scoring pattern. Source: Wu et al. [61].

save time. Patients are categorized into low, medium, or high-risk groups based on five criteria: BMI, unexplained weight loss, dietary intake, the severity of hepatitis, and the impact of current complications on food intake (such as ascites or general fluid overload) [61].

The assessment process involves three key steps: (1) patients with alcoholic hepatitis or those receiving tube feeding are immediately classified as high risk without further evaluation; (2) patients who do not have alcoholic hepatitis and are not on tube feeding are evaluated for fluid overload and its effects on food intake and weight loss; and (3) patients without fluid overload are assessed based on their nutritional status, including BMI, unexplained weight loss, and daily dietary intake. Patients are classified as low risk with a score of 0, moderate risk with a score of 1, and high risk with a score ranging from 2 to 7 (**Figure 10**) [61].

5. Challenges in nutrition screening and assessment

Nutrition screening and assessment in critically ill patients face several challenges due to their dynamic clinical status. Rapid changes in the patient's condition require frequent reassessments to ensure accurate nutrition evaluations. Medical interventions such as mechanical ventilation, sedation, and fluid resuscitation further complicate this process, as these therapies can alter nutritional parameters. One key concern is refeeding syndrome, which occurs when malnourished patients are fed too rapidly, causing imbalances in electrolytes like phosphorus, potassium, and magnesium, leading to severe metabolic and hormonal disturbances. Hypophosphatemia can impair

cell function, low potassium may lead to cardiac issues, and magnesium deficiency affects ATP production, risking heart dysfunction. Increased glucose uptake can trigger hyperglycemia, ketoacidosis, and fluid retention, posing risks such as pulmonary edema or heart failure [62, 63].

Resource limitations also hinder effective nutrition screening and assessment in some settings. The availability of specialized equipment or trained personnel is often lacking, further complicating the care of critically ill patients. Proper tools and expertise are essential to identify patients at risk and prevent conditions like refeeding syndrome, emphasizing the need for adequate resources in clinical environments.

6. Strategies to improve nutritional outcomes

Nutritional care for critically ill patients can be best optimized with a comprehensive, multi-modal approach. This includes a multidisciplinary team of dieticians, nurses, physicians, and other health professionals to cover all aspects of nutritional care for the patient. All members bring valuable input in observing, mapping, and altering nutritional interventions, and this serves to enhance holistic patient care. Early and ongoing nutrition support is of primary importance. The earlier the nutrition intervention is instituted and altered continuously, when possible, based on the ever-changing condition of the patient, the better the recuperation and fewer complications. Equally, care is standardized with the use of evidence-based protocols and guidelines, and there will hence be minimal variations between different practitioners and generally better outcomes for patients. This systematic approach minimizes variability in practice; thus, it offers more reliable and effective nutritional interventions in the ICU environment.

7. Conclusion

Nutritional screening and assessment are cornerstones in the care of the critically ill. Healthcare providers are in a good position to have a positive influence on the rate of recovery and outcomes if they promptly identify those patients with a high risk of malnutrition and offer timely, individualized nutritional interventions. While many of the challenges continue, there is promise for improved nutritional care in this vulnerable population through new developments in the tools and techniques, along with multidisciplinary approaches for improvement of the identification and intervention.

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References

[1] Mark S, Jami E, Jodi W. A Guide to the Nutritional Assessment and Treatment of the Critically Ill Patient. 2021. Available from: https://www.aarc.org/wp-content/uploads/2014/11/nutrition_guide.pdf

[2] Sungurtekin H, Sungurtekin U, Oner O, Okke D. Nutrition assessment in critically ill patients. Nutrition in Clinical Practice. 2008;**23**(6):635-641

[3] Kubrak C, Jensen L. Malnutrition in acute care patients: A narrative review. International Journal of Nursing Studies. 2007;**44**(6):1036-1054

[4] Rodríguez L, Cervantes E, Ortiz R. Malnutrition and gastrointestinal and respiratory infections in children: A public health problem. International Journal of Environmental Research and Public Health. 2011;**8**(4):1174-1205

[5] Malnutrition [Internet]. Available from: https://www.who.int/health-topics/malnutrition [Accessed: September 6, 2024]

[6] Swan WI, Vivanti A, Hakel-Smith NA, Hotson B, Orrevall Y, Trostler N, et al. Nutrition care process and model update: Toward realizing people-centered care and outcomes management. Journal of the Academy of Nutrition and Dietetics. 2017;**117**(12):2003-2014

[7] Zhang JM, An J. Cytokines, inflammation, and pain. International Anesthesiology Clinics. 2007;**45**(2):27-37

[8] Demling RH. Nutrition, anabolism, and the wound healing process: An overview. Eplasty. 2009;**9**:e9

[9] Preiser JC, Ichai C, Orban JC, Groeneveld ABJ. Metabolic response to the stress of critical illness. British Journal of Anaesthesia. 2014;**113**(6):945-954

[10] Lee Z-Y, Ibrahim NA, Mohd YBN. Prevalence and duration of reasons for enteral nutrition feeding interruption in a tertiary intensive care unit. Nutrition. 2018;**53**:26-33. DOI: 10.1016/j.nut.2017.11.014

[11] Rajendram R, Khan MF. The use of nutritional screening tools in the intensive therapy unit. Anaesthesia Pain & Intensive Care. 2019;**23**(2):231-236. DOI: 10.35975/apic.v23i2.1081

[12] Academy of Nutrition and Dietetics. Abridged Cate Process Terminology (NCPT). Chicago: Academy of Nutrition and Dietetics; 2017. Available from: https://www.andeal.org/vault/2440/web/files/EAL/NCP_EAL_201711.pdf

[13] Nakanishi N, Takashima T, Oto J. Muscle atrophy in critically ill patients: A review of its cause, evaluation, and prevention. The Journal of Medical Investigation. 2020;**67**(1.2):1-10

[14] 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 (ASPEN). JPEN. Journal of Parenteral and Enteral Nutrition. 2016;**40**(2):159-211

[15] Domenech-Briz V, Gea-Caballero V, Czapla M, Chover-Sierra E, Juárez-Vela R, Santolalla Arnedo I, et al. Importance of nutritional assessment tools in the critically ill patient:

A systematic review. Frontiers in Nutrition. 2023;**9**:1073782. DOI: 10.3389/fnut.2022.1073782

[16] Correia MITD. Nutrition screening vs nutrition assessment: What's the difference? Nutrition in Clinical Practice. 2018;**33**(1):62-72

[17] Ukleja A, Gilbert K, Mogensen KM, Walker R, Ward CT, Ybarra J, et al. Standards for nutrition support: Adult hospitalized patients. Nutrition in Clinical Practice. 2018;**33**:906-920. DOI: 10.1002/ncp.10204

[18] Cederholm T, Barazzoni R, Austin P, Ballmer P, Biolo G, Bischoff SC, et al. ESPEN guidelines on definitions and terminology of clinical nutrition. Clinical Nutrition. 2017;**36**:49-64. DOI: 10.1016/j.clnu.2016.09.004

[19] Lee Z-Y, Heyland DK. Determination of nutrition risk and status in critically ill patients: What are our considerations? Nutrition in Clinical Practice. 2019;**34**(1):96-111. DOI: 10.1002/ncp.10214

[20] Reber E, Gomes F, Vasiloglou MF, Schuetz P, Stanga Z. Nutritional risk screening and assessment. Journal of Clinical Medicine. 2019;**8**(7):1065. DOI: 10.3390/jcm8071065

[21] Serón-Arbeloa C, Labarta-Monzón L, Puzo-Foncillas J, Mallor-Bonet T, Lafita-López A, Bueno-Vidales N, et al. Malnutrition screening and assessment. Nutrients. 2022;**14**:2392. DOI: 10.3390/nu14122392nu14122392

[22] Guaitoli PR, Jansma EP, de Vet HC. Nutrition screening tools: Does one size fit all? A systematic review of screening tools for the hospital setting. Clinical Nutrition. 2014;**33**(1):39-58

[23] Skipper A, Ferguson M, Thompson K, Castellanos VH, Porcari J. Nutrition screening tools: An analysis of the evidence. Journal of Parenteral and Enteral Nutrition. 2012;**36**(3):292-298

[24] Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, Casaer MP, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clinical Nutrition. 2019;**38**(1):48-79

[25] Hill A, Elke G, Weimann A. Nutrition in the intensive care unit-A narrative review. Nutrients. 2021;**13**(8):2851. DOI: 10.3390/nu13082851

[26] Kondrup J, Rasmussen HH, Hamberg O, Stanga Z, Ad Hoc ESPEN Working Group. Nutritional risk screening (NRS 2002): A new method based on an analysis of controlled clinical trials. Clinical Nutrition (Edinburgh, Scotland). 2003;**22**(3):321-336. DOI: 10.1016/s0261-5614(02)00214-5

[27] Elia M. The "MUST" Report. Nutritional Screening of Adults: A Multidisciplinary Responsibility. Development and Use of the "Malnutrition Universal Screening Tool" ('MUST') for Adults; Chairman of MAG and Editor Advancing Clinical Nutrition, a Standing Committee of BAPEN. Redditch, UK: BAPEN; 2003

[28] Majari K, Imani H, Hosseini S, Amirsavadkouhi A, Ardehali SH, Khalooeifard R. Comparison of modified NUTRIC, NRS-2002, and MUST scores in Iranian critically ill patients admitted to intensive care units: A prospective cohort study. JPEN. Journal of Parenteral and Enteral Nutrition. 2021;**45**(7):1504-1513. DOI: 10.1002/jpen.2031

[29] Auiwattanakul S, Chittawatanarat K, Chaiwat O, Morakul S, Kongsayreepong S, Ungpinitpong W, et al. Effects of nutrition factors on mortality and sepsis occurrence in a

multicenter university-based surgical intensive care unit in Thailand (THAI-SICU study). Nutrition. 2019;**58**:94-99

[30] de Vries MC, Koekkoek WK, Opdam MH, van Blokland D, van Zanten AR. Nutritional assessment of critically ill patients: Validation of the modified NUTRIC score. European Journal of Clinical Nutrition. 2018;**72**(3):428-435. DOI: 10.1038/s41430-017-0008-7

[31] Heyland DK, Dhaliwal R, Jiang X, et al. Identifying critically ill patients who benefit the most from nutrition therapy: The development and initial validation of a novel risk assessment tool. Critical Care. 2011;**15**:R268. DOI: 10.1186/cc10546

[32] Rahman A, Hasan RM, Agarwala R, Martin C, Day AG, Heyland DK. Identifying critically-ill patients who will benefit most from nutritional therapy: Further validation of the "modified NUTRIC" nutritional risk assessment tool. Clinical Nutrition. 2016;**35**(1):158-162

[33] Oliveira ML, Heyland DK, Silva FM, Rabito EI, Rosa M, Tarnowski MDS, et al. Complementarity of modified NUTRIC score with or without C-reactive protein and subjective global assessment in predicting mortality in critically ill patients. Complementariedade do escore NUTRIC modificado com ou sem proteína C-reativa e avaliação subjetiva global na predição de mortalidade em pacientes críticos. Revista Brasileira de terapia intensiva. 2019;**31**(4):490-496. DOI: 10.5935/0103-507X.20190086

[34] Williams DG, Villalta E, Aronson S, Murray S, Blitz J, Kosmos V, et al. Tutorial: Development and implementation of a multidisciplinary preoperative nutrition optimization clinic. Journal of Parenteral and Enteral Nutrition. 2020;**44**(7):1185-1196

[35] Wischmeyer PE, Carli F, Evans DC, Guilbert S, Kozar R, Pryor A, et al. American society for enhanced recovery and perioperative quality initiative joint consensus statement on nutrition screening and therapy within a surgical enhanced recovery pathway. Anesthesia & Analgesia. 2018;**126**(6):1883-1895

[36] Tandon P, Raman M, Mourtzakis M, Merli M. A practical approach to nutritional screening and assessment in cirrhosis. Hepatology (Baltimore, Md.). 2017;**65**(3):1044-1057. DOI: 10.1002/hep.29003

[37] Kesari A, Noel JY. Nutritional Assessment. Treasure Island (FL): StatPearls Publishing; 2024. Available from: https://www.ncbi.nlm.nih.gov/books/NBK580496/ [Accessed: April 10, 2023]

[38] World Health Organization. Physical Status: The Use and Interpretation of Anthropometry, Report of a WHO Expert Committee. Geneva, Switzerland: World Health Organization; 1995

[39] Bioelectrical Impedance Analysis. Body Composition Analysis Las Vegas. Henderson Weight Loss [Internet]. Available from: https://valhallawellness.com/conditions/bioelectrical-impedance/

[40] UNICEF. UNICEF [Internet]. UNICEF; 2023. Available from: https://www.unicef.org/

[41] Caballero B. Encyclopedia of Human Nutrition. Netherlands: Elsevier Science; 2013

[42] Cederholm T, Bosaeus I, Barazzoni R, Bauer J, van Gossum A, Klek S, et al. Diagnostic criteria for malnutrition—An ESPEN consensus

statement. Clinical Nutrition. 2015;**34**:335-340

[43] Weimann A, Hartl WH, Adolph M, Angstwurm M, Brunkhorst FM, Edel A, et al. Erfassung und apparatives Monitoring des Ernährungsstatus von Patient* innen auf der Intensiv-und Intermediate Care Station. Medizinische Klinik-Intensivmedizin und Notfallmedizin. 2022;**117**(Suppl. 2):37-50

[44] Siobal MS, Baltz JE, RD-AP CN. Nutritional Assessment and Treatment of the Critically Ill Patient. America: American Association for Respiratory Care; 2021

[45] Heymsfield SB, Gonzalez MC, Lu J, Jia G, Zheng J. Skeletal muscle mass and quality: Evolution of modern measurement concepts in the context of sarcopenia. The Proceedings of the Nutrition Society. 2015;**74**:355-366

[46] Tillquist M, Kutsogiannis DJ, Wischmeyer PE, Kummerlen C, Leung R, Stollery D, et al. Bedside ultrasound is a practical and reliable measurement tool for assessing quadriceps muscle layer thickness. Journal of Parenteral and Enteral Nutrition. 2014;**38**:886-890

[47] Keller U. Nutritional laboratory markers in malnutrition. Journal of Clinical Medicine. 2019;**8**(6):775. DOI: 10.3390/jcm8060775

[48] Kathleen Mahan L, Escott-Stump S, Raymond J. Krause's Food & Nutrition Care Process. Philadelphia, PA: Saunders; 2021

[49] Esper DH. Utilization of nutrition-focused physical assessment in identifying micronutrient deficiencies. Nutrition in Clinical Practice. 2015;**30**:194-202

[50] Fischer M, JeVenn A, Hipskind P. Evaluation of muscle and fat loss as diagnostic criteria for malnutrition. Nutrition in Clinical Practice: Official Publication of the American Society for Parenteral and Enteral Nutrition. 2015;**30**(2):239-248. DOI: 10.1177/0884533615573053

[51] Hummell AC, Cummings M. Role of the nutrition-focused physical examination in identifying malnutrition and its effectiveness. Nutrition in Clinical Practice. 2022;**37**(1):41-49. DOI: 10.1002/ncp.10797. Epub 2021 Nov 9

[52] Mehta Y, Sunavala JD, Zirpe K, Tyagi N, Garg S, Sinha S, et al. Practice guidelines for nutrition in critically ill patients: A relook for Indian scenario. Indian Journal of Critical Care Medicine: Peer-Reviewed, Official Publication of Indian Society of Critical Care Medicine. 2018;**22**(4):263-273. DOI: 10.4103/ijccm.IJCCM_3_18

[53] Food and Agriculture Organization of the United Nations. Dietary Assessment: A Resource Guide to Method Selection and Application in Low Resource Settings. Rome, Italy: Food and Agriculture Organization of the United Nations; 2018

[54] Cederholm T, Jensen GL, Correia MITD, Gonzalez MC, Fukushima R, Higashiguchi T, et al. GLIM criteria for the diagnosis of malnutrition – A consensus report from the global clinical nutrition community. Journal of Cachexia, Sarcopenia and Muscle. 2019;**10**:207-217. DOI: 10.1002/jcsm.12383

[55] Norman K, Stobaus N, Gonzalez MC, Schulzke JD, Pirlich M. Hand grip strength: Outcome predictor and marker of nutritional status. Clinical Nutrition. 2011;**30**:135-142

[56] Bakshi N, Singh K. Nutrition assessment in patients undergoing liver transplant. Indian Journal of Critical Care Medicine: Peer-Reviewed, Official Publication of Indian Society of Critical Care Medicine. 2014;**18**(10):672

[57] Keith JN. Bedside nutrition assessment past, present, and future: A review of the subjective global assessment. Nutrition in Clinical Practice. 2008;**23**(4):410-416

[58] Detsky AS, McLaughlin JR, Baker JP, et al. What is subjective global assessment of nutritional status? JPEN Journal of Parenteral and Enteral Nutrition. 1987;**11**(1):8-13

[59] Bector S, Vagianos K, Suh M, Duerksen DR. Does the subjective global assessment predict outcome in critically ill medical patients? Journal of Intensive Care Medicine. 2016;**31**(7):485-489. DOI: 10.1177/0885066615596325

[60] Bakshi N, Singh K, Seth V, Jerath SJ. Impact of malnutrition on nutritional and nonnutritional factors in end stage liver disease. Asian Journal of Clinical Nutrition. 2017;**9**:77-88

[61] Wu Y, Zhu Y, Feng Y, et al. Royal free hospital-nutritional prioritizing tool improves the prediction of malnutrition risk outcomes in liver cirrhosis patients compared with nutritional risk screening 2002. British Journal of Nutrition. 2020;**124**(12):1293-1302. DOI: 10.1017/S0007114520002366

[62] Hearing SD. Refeeding syndrome. BMJ. 2004;**328**(7445):908-909

[63] Mehanna HM, Moledina J, Travis J. Refeeding syndrome: What it is, and how to prevent and treat it. BMJ. 2008;**336**(7659):1495-1498

Chapter 3

Enteral Nutrition in Critically Ill Patients Using Vasoactive Drugs

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Abstract

The administration of enteral nutritional therapy (NT) in critically ill patients requiring vasopressor support due to hemodynamic instability demands great attention at the initiation and maintenance of therapy. Early enteral nutrition, started within 24–48 hours after admission to the intensive care unit (ICU), is essential for better clinical outcomes. However, when to start therapy is uncertain, as there are controversies regarding the safe dose of vasopressors that allows the initiation of nutritional therapy. Although no specific cutoff value has been identified, the patient's hemodynamic stability and clinical signs are crucial to evaluate the tolerance to nutritional therapy. Therefore, low and stable doses of vasopressors are preferable, and rigorous clinical monitoring is crucial for the safety of nutritional therapy in critically ill patients.

Keywords: enteral nutrition, nutritional therapy, vasopressors, intensive care, hemodynamic stability

1. Introduction

Enteral nutrition (EN) is a critical component in managing patients in intensive care units (ICUs), particularly those who are critically ill. EN supports gastrointestinal function, preserves mucosal integrity, and reduces the risk of infections by maintaining gut flora and preventing bacterial translocation [1]. Studies have shown that EN can help decrease complications, such as infections, and shorten hospital stays, ultimately leading to better clinical outcomes for critically ill patients [2]. However, administering EN to patients requiring vasopressors presents specific challenges, particularly regarding the safest timing for initiation and appropriate vasopressor dosing.

For patients requiring vasopressors, the initiation of EN should be gradual to minimize the risk of feeding intolerance and complications such as non-occlusive intestinal ischemia [2]. A gradual introduction of EN allows the gastrointestinal tract (GIT) to adapt to the nutrient load, prevents metabolic overload, and facilitates monitoring for signs of intolerance, such as abdominal distension and increased gastric residuals. Current guidelines for nutritional therapy (NT) in critically ill

patients recommend starting EN at low infusion rates, progressively increasing as tolerated by the patient [1, 3–5]. During the initial stabilization phase, the goal is to provide between 20 and 25 kcal/kg/day, adjusting as needed based on tolerance and hemodynamic response [4]. This approach ensures safe nutrition delivery without compromising patient stability and allows for continuous gastrointestinal function and hemodynamic status assessment [3–5]. Therefore, the management of EN must be individualized, taking into account each patient's unique hemodynamic conditions and tissue perfusion status.

2. Vasopressors and their effects on the gastrointestinal tract

Vasopressors are essential in managing hypotension in critically ill patients, but their hemodynamic and metabolic effects on the gastrointestinal tract vary depending on the type of drug used. Understanding these effects is crucial for managing enteral nutrition in patients on vasopressors. Below, we discuss the most-used vasopressors and their specific impacts on GIT.

2.1 Norepinephrine

Norepinephrine is a potent alpha-adrenergic agonist commonly used to increase systemic vascular resistance and mean arterial pressure (MAP) through peripheral vasoconstriction. At doses above 0.3 μg/kg/min, there is an elevated risk of non-occlusive ischemia, particularly in patients with limited cardiovascular reserve. Research indicates that while norepinephrine increases splanchnic oxygen extraction, there is no corresponding increase in jejunal perfusion, suggesting that the redistribution of blood flow may be insufficient to prevent intestinal mucosal ischemia [6, 7]. Furthermore, the NUTRIREA-2 study highlighted that enteral nutrition could be safely initiated in patients receiving up to 0.56 μg/kg/min of norepinephrine. However, caution is warranted above 0.3 μg/kg/min due to a significant rise in gastrointestinal complications, including mesenteric ischemia [2]. As stated by the DGEM guidelines, early enteral nutrition (EN) can harm patients receiving norepinephrine doses greater than 0.5 μg/kg/min [8]. They recommend initiating EN only when vasopressor doses are stable or decreasing. Additionally, they advise starting EN at a low flow rate while closely monitoring potential hemodynamic effects [8]. Ohbe et al. reported that when norepinephrine doses exceeded 0.3 μg/kg/min, early EN did not benefit survival [9]. The NUTRIREA-3 study demonstrated that, in ventilated patients with shock who were receiving norepinephrine doses above 0.5 μg/kg/min, early full EN was associated with an increased risk of gastrointestinal complications [10].

2.2 Dopamine

Dopamine has dose-dependent effects. Low doses (1–5 μg/kg/min) primarily induce splanchnic and renal vasodilation by acting on dopaminergic receptors. At intermediate doses (5–10 μg/kg/min), dopamine activates beta-1 adrenergic receptors, increasing cardiac output. At higher doses (>10 μg/kg/min), alpha-adrenergic effects predominate, causing systemic vasoconstriction [7]. While low doses can improve splanchnic perfusion, higher doses may exacerbate intestinal hypoperfusion and increase the risk of ischemia.

Vasopressor	Mechanism of Action	Effect on GIT
Norepinephrine	Potent alpha-adrenergic agonist	Splanchnic vasoconstriction, risk of mesenteric ischemia at high doses
Dopamine	Dose-dependent (dopaminergic, beta-1, alpha)	Enhances splanchnic perfusion at low doses; risk of intestinal hypoperfusion at high doses
Dobutamine	Beta-1 adrenergic agonist	Increases cardiac output and oxygen delivery to the GIT; limited effect on splanchnic perfusion
Epinephrine	Alpha and beta-adrenergic agonist	Significant splanchnic vasoconstriction, increased risk of intestinal ischemia at high doses
Vasopressin	Non-adrenergic vasoconstrictor	Significant reduction in splanchnic perfusion, high risk of mesenteric ischemia

Table 1.
Mechanism of action and gastrointestinal effects of different vasopressors.

2.3 Dobutamine

Dobutamine is a beta-1 adrenergic agonist that increases cardiac output and causes mild vasodilation. It can enhance oxygen delivery to the GIT, especially in patients with ventricular dysfunction. Still, its vasodilatory effect is limited and may not adequately counteract the splanchnic vasoconstriction induced by other vasopressors, particularly in septic shock state [7].

2.4 Epinephrine

Epinephrine is an alpha and beta-adrenergic agonist that can increase cardiac output but causes significant splanchnic vasoconstriction at higher doses, which can reduce blood flow to the GIT and heighten the risk of intestinal ischemia [7].

2.5 Vasopressin

Vasopressin, a potent vasoconstrictor, works through a non-adrenergic mechanism and is useful in patients who are refractory to other catecholamines. However, it can significantly decrease splanchnic blood flow and increase the risk of mesenteric ischemia, particularly in patients with hyperdynamic shock states like septic shock [7].

Table 1 summarizes the mechanisms of action of vasopressors and their effects on GIT.

3. Risks of gastrointestinal hypoperfusion and ischemia in critically ill patients

The gastrointestinal tract (GIT) is particularly vulnerable to hypoperfusion, especially during shock states and when vasopressors are being used. Under normal conditions, the GIT receives approximately 20–25% of cardiac output, crucial for maintaining mucosal integrity, supporting digestive functions, and preventing bacterial translocation [5]. The splanchnic circulation has a high capacity for autoregulation, allowing it to maintain adequate perfusion despite variations in blood flow. However, during shock states such as septic or cardiogenic shock, blood flow is significantly redistributed to prioritize vital organs like the brain and heart at the expense of the GIT [11]. This

redistribution is exacerbated by using vasopressors, which induce intense vasoconstriction in the splanchnic circulation, potentially leading to reduced oxygen delivery, tissue hypoxia, and non-occlusive intestinal ischemia [6].

Intestinal villi are especially susceptible to hypoperfusion due to their complex microvascular architecture, which, while effective for gas exchange, also makes them vulnerable under low-flow conditions [12]. Reduced capillary perfusion can lead to villus necrosis and compromise the mucosal barrier, increasing the risk of bacterial translocation and systemic infection, thereby worsening the clinical status of critically ill patients [11]. Additionally, prolonged hypoperfusion coupled with vasopressors can lead to an exaggerated local inflammatory response in the GIT, resulting in mucosal edema, erosions, and ulcerations that further impair the intestinal barrier function and may lead to multiple organ dysfunction [13]. Therefore, continuous monitoring of splanchnic perfusion and careful adjustment of vasopressor therapy are essential to mitigate the risk of non-occlusive intestinal ischemia and its consequences in critically ill patients.

4. Clinical guidelines and current evidence

ASPEN and ESPEN recommend caution when initiating enteral nutrition in critically ill patients requiring vasopressors, emphasizing that enteral nutrition should only be considered when there is hemodynamic stability or a reduction in the doses of vasoactive drugs [1, 3].

Vasopressors are often required in shock states to increase cardiac output and enhance oxygen delivery to cells. Some guidelines, such as the most recent Surviving Sepsis Campaign, recommend the early use of vasopressors, even concurrently with fluid resuscitation [7]. In other situations, such as cardiogenic shock, patients may experience fluid overload, making vasopressors or inotropes play a more crucial role.

EN should be introduced gradually, with strict monitoring for signs of feeding intolerance and mesenteric ischemia. The BRASPEN guidelines also emphasize the need to ensure hemodynamic stability before starting EN, suggesting that enteral nutrition should be postponed until adequate clinical and hemodynamic stabilization is achieved in hemodynamically unstable patients [4]. The Society of Critical Care Medicine (SCCM) and the American Society for Parenteral and Enteral Nutrition (ASPEN) also recommend waiting for hemodynamic resuscitation before initiating enteral nutrition (EN) [14]. The European Society of Intensive Care Medicine (ESICM) suggests delaying EN until tissue perfusion goals are achieved and recommends starting low-dose EN as soon as shock is controlled [15]. On the other hand, according to the ESPEN guidelines, there is insufficient evidence to support that recommendation for patients with septic shock who are using vasopressors or inotropes [3].

5. Strategies for clinical implementation

In clinical practice, when considering enteral nutrition for critically ill patients on vasopressors, a personalized approach is crucial:

- Continuous monitoring: Monitoring for signs of feeding intolerance, such as abdominal distension, vomiting, and increased gastric residuals, as well as assessing splanchnic perfusion, is essential to adjust nutritional therapy and

prevent severe complications like intestinal ischemia. Close monitoring of serum lactate levels is also essential, as elevated lactate can indicate hypoperfusion and early intestinal ischemia, guiding adjustments in vasopressor therapy and enteral nutrition administration to avoid serious complications.

- Gradual introduction of EN: Enteral nutrition should be initiated gradually, with increases in infusion rates as tolerated by the patient. The goal is to reach approximately 70–80% of the estimated caloric needs by the 4th day, adjusting the infusion rate based on the patient's clinical response and gastrointestinal tolerance to ensure adequate nutritional intake without compromising hemodynamic stability.

- Consideration of parenteral nutrition: Parenteral nutrition should also be avoided in hemodynamically unstable patients or those on high doses of vasopressors due to its association with increased complications and higher mortality rates. Therefore, enteral and parenteral nutrition should be deferred until adequate hemodynamic stability is achieved.

6. Potential complications and management

Feeding intolerance is a common complication in critically ill patients receiving vasopressors, marked by symptoms such as elevated gastric residuals and vomiting, which may signal an increased risk of aspiration and intestinal ischemia. Studies have indicated that initiating enteral nutrition in hemodynamically unstable patients increases the risk of gastrointestinal complications (see **Table 2**) and prolongs ICU stay [5, 16]. Additionally, non-occlusive intestinal ischemia can be a severe complication associated with enteral nutrition in these patients, often suspected in the presence of symptoms like abdominal distension, disproportionate abdominal pain, unexplained metabolic acidosis, and gastrointestinal bleeding [5, 17]. Therefore, a cautious approach to initiating enteral nutrition, guided by careful monitoring and individualized assessment, is essential to minimize these risks.

Table 2 summarizes the most common complications associated with EN in critically ill patients using vasoactive drugs.

Authors	Vasopressors information	Complications
Merchan et al. [18]	Norepinephrine: 0.14 μg/kg/min	Gastric residual volumes >250 mL (74%), aspiration event (17%), emesis (9%)
Flordelís Lasierra et al. [19]	Norepinephrine: 0.32 μg/kg/min, epinephrine: 0.11 μg/kg/min, dopamine: 6.35 μg/kg/min, dobutamine: 7.19 μg/kg/min	High gastric residual volumes (8.1%), abdominal distention (21.6%), diarrhea (27.0%), constipation (46.0%), vomiting/regurgitation (2.7%), broncho aspiration (2.7%), gastrointestinal bleeding (2.7%)
Patel et al. [20]	Norepinephrine: 0.08 μg/kg/min	Vomiting (13%), Candida isolation (7%)
Ohbe et al. [21]	Norepinephrine: 0.03 μg/kg/min	Pneumonia (9%), bowel ischemia (0%)
Reignier et al. [2]	Norepinephrine: 0.56 mg kg/min	Vomiting (34%), diarrhea (33%), bowel ischemia (2%), acute colonic pseudo-obstruction (1%)

Adapted from: Wang et al. [22].

Table 2.
Most common complications associated with the use of vasoactive drugs in critically ill patients receiving enteral nutrition.

7. Conclusion

Deciding when to start enteral nutrition in critically ill patients on vasopressors is a complex and multifaceted challenge. There is no consensus on the maximum dose of vasopressors that contraindicates enteral nutrition, as individual needs and hemodynamic responses can vary widely among patients. However, the literature suggests that initiating EN in patients on high or escalating doses of vasopressors is associated with a higher risk of complications, primarily due to splanchnic hypoperfusion, which can result in feeding intolerance or, in more severe cases, non-occlusive intestinal ischemia.

Therefore, achieving macro-hemodynamic and micro-hemodynamic stability is a prerequisite for the safe initiation of EN. Current evidence suggests that early initiation of enteral nutrition after hemodynamic stabilization can reduce complications during ICU stay, including shorter duration of mechanical ventilation, lower rates of hospital-acquired infections, and better rehabilitation outcomes post-discharge. Thus, a cautious and individualized approach is essential, tailoring nutritional therapy according to the patient's clinical condition and response. Continuous monitoring of gastrointestinal function, splanchnic perfusion, tissue perfusion, and the clinical response are crucial for adjusting nutritional management and minimizing risks. With a careful and informed approach, nutrition can be safely and effectively integrated into the care of critically ill patients, significantly contributing to improved clinical outcomes and overall patient recovery.

Conflict of interest

The authors declare no conflict of interest.

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References

[1] Compher C, Bingham AL, McCall M, Patel J, Rice TW, Braunschweig C, et al. Guidelines for the provision of nutrition support therapy in the adult critically ill patient: The American Society for Parenteral and Enteral Nutrition. Journal of Parenteral and Enteral Nutrition. 2022;**46**(1):12-41. DOI: 10.1002/jpen.2267

[2] Reignier J, Boisrame-Helms J, Brisard L, Lascarrou JB, Ait Hssain A, Anguel N, et al. Enteral versus parenteral early nutrition in ventilated adults with shock: A randomized, controlled, multicenter, open-label, parallel-group study (NUTRIREA-2). Lancet. 2018;**391**(10116):133-143. DOI: 10.1016/S0140-6736(17)32146-3

[3] Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, Casaer MP, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clinical Nutrition. 2019;**38**(1):48-79. DOI: 10.1016/j.clnu.2018.08.037

[4] Castro MG, Ribeiro PC, de Matos LBN, Abreu HB, de Assis T, Barreto PA, et al. Diretriz BRASPEN de Terapia Nutricional no Paciente Grave. BRASPEN Journal. 2023;**38**(2 Suppl. 2): ISSN 2764-1546

[5] Simões Covello LH, Gava-Brandolis MG, Castro MG, Dos Santos Netos MF, Manzanares W, Toledo DO. Vasopressors and nutrition therapy: Safe dose for the outset of enteral nutrition? Critical Care Research and Practice. 2020;**10**:1095693. DOI: 10.1155/2020/1095693

[6] Meier-Hellmann A, Specht M, Hannemann L, Hassel H, Bredle DL, Reinhart K. Splanchnic blood flow is greater in septic shock treated with norepinephrine than in severe sepsis. Intensive Care Medicine. 1996;**22**(12):1354-1359. DOI: 10.1007/BF01709551

[7] Evans L, Rhodes A, Alhazzani W, Antonelli M, Coopersmith CM, French C, et al. Surviving sepsis campaign: International guidelines for management of sepsis and septic shock 2021. Intensive Care Medicine. 2021;**47**(11):1181-1247. DOI: 10.1007/s00134-021-06506-y

[8] Elke G, Hartl WH, Kreymann KG, Adolph M, Felbinger TW, Graf T, et al. Clinical nutrition in critical care medicine—Guideline of the German Society for Nutritional Medicine (DGEM). Clinical Nutrition ESPEN. 2019;**33**:220-275

[9] Ohbe H, Jo T, Matsui H, Fushimi K, Yasunaga H. Differences in effect of early enteral nutrition on mortality among ventilated adults with shock requiring low-, medium-, and high-dose noradrenaline: A propensity-matched analysis. Clinical Nutrition. 2020;**39**(2):460-467. DOI: 10.1016/j.clnu.2019.02.020

[10] Reignier J, Plantefeve G, Mira JP, Argaud L, Asfar P, Aissaoui N, et al. Low versus standard calorie and protein feeding in ventilated adults with shock: A randomised, controlled, multicentre, open-label, parallel-group trial (NUTRIREA-3). Lancet Respiratory Medicine. 2023;**11**(7):602-612. DOI: 10.1016/S2213-2600(23)00092-9

[11] De Backer D, Creteur J, Preiser JC, Dubois MJ, Vincent JL. Microvascular blood flow is altered in patients with sepsis. American Journal of

Respiratory and Critical Care Medicine. 2002;**166**(1):98-104. DOI: 10.1164/rccm.200109-016OC

[12] Fink MP, Delude RL. Epithelial barrier dysfunction: A unifying theme to explain the pathogenesis of multiple organ dysfunction at the cellular level. Critical Care Clinics. 2005;**21**(2):177-196. DOI: 10.1016/j.ccc.2005.01.005

[13] Deitch EA. Gut-origin sepsis: Evolution of a concept. The Surgeon. 2012;**10**(6):350-356. DOI: 10.1016/j.surge.2012.03.003

[14] 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. Critical Care Medicine. 2016;**44**(2):390-438. DOI: 10.1177/0148607115621863

[15] Reintam, Blaser A, Starkopf J, Alhazzani W, Berger MM, Casaer MP, Deane AM, et al. Early enteral nutrition in critically ill patients: ESICM clinical practice guidelines. Intensive Care Medicine. 2017;**43**(3):380-398. DOI: 10.1007/s00134-016-4665-0

[16] Wells DL. Provision of enteral nutrition during vasopressor therapy for hemodynamic instability: An evidence-based review. Nutrition in Clinical Practice. 2012;**27**(4):521-526. DOI: 10.1177/0884533612448480

[17] De Branbandere K, De Waele B, Delvaux G. Colonic ischemia and perforation associated with enteral feeding through an ileal tube. Nutrition in Clinical Practice. 2010;**25**(3):301-303. DOI: 10.1177/0884533610368705

[18] Merchan C, Altshuler D, Aberle C, Papadopoulos J, Schwartz D. Tolerability of enteral nutrition in mechanically ventilated patients with septic shock who require vasopressors. Journal of Intensive Care Medicine. 2016;**32**(9):540-546. DOI: 10.1177/0885066616656799

[19] Flordelís, Lasierra JL, Perez-Vela JL, Umezawa Makikado LD, Torres Sanchez E, Colino Gomez L, Maroto Rodríguez B, et al. Early enteral nutrition in patients with hemodynamic failure following cardiac surgery. Journal of Parenteral and Enteral Nutrition. 2013;**39**(2):154-162. DOI: 10.1177/0148607113504219

[20] Patel JJ, Kozeniecki M, Peppard WJ, Peppard SR, Zellner-Jones S, Graf J, et al. Phase 3 pilot randomized controlled trial comparing early trophic enteral nutrition with "No enteral nutrition" in mechanically ventilated patients with septic shock. Journal of Parenteral and Enteral Nutrition. 2020;**44**(5):866-873. DOI: 10.1002/jpen.1706

[21] Ohbe H, Jo T, Yamana H, Matsui H, Fushimi K, Yasunaga H. Early enteral nutrition for cardiogenic or obstructive shock requiring venoarterial extra-corporeal membrane oxygenation: A nationwide inpatient database study. Intensive Care Medicine. 2018;**44**(8):1258-1265. DOI: 10.1007/s00134-018-5319-1

[22] Wang L, Zhong X, Yang H, Yang J, Zhang Y, Zou X, et al. When can we start early enteral nutrition safely in patients with shock on vasopressors? Clinical Nutrition ESPEN. 2024;**61**:28-36. DOI: 10.1016/j.clnesp.2024.03.007

Chapter 4

Perspective Chapter: Parenteral Nutrition in Intensive Care

Fulya Çabuk and Mustafa Çetiner

Abstract

Current guidelines state that early enteral nutrition, initiated within 48 hours, is superior to parenteral nutrition as the first choice in intensive care patients. However, it is an important tool that makes it possible to feed patients with Gastrointestinal (GI) dysfunction or a problem that prevents enteral nutrition. It has been shown that the administration of parenteral nutrition in addition to inadequate enteral nutrition can improve clinical outcomes. The parenteral route is less physiological than enteral nutritional support. Although it has a positive effect on the patient's clinical course when used appropriately, improper use causes increased infectious complications, metabolic abnormalities and increased medical costs. In these respects, parenteral nutrition is important in intensive care. This chapter aims to evaluate the current parenteral nutrition strategy in the intensive care unit.

Keywords: intensive care, parenteral nutrition, enteral, complication, indication

1. Introduction

Nutrition is an essential component of patient care; however, the optimal nutritional strategy for patients in the intensive care unit (ICU) remains a subject of debate. Publications and updated international clinical guidelines have provided guidance on nutritional therapy in critical illnesses. However, applying this knowledge to practice becomes challenging when individual factors, such as disease stage and body composition, are considered. ICU patients are at risk of energy deficits during their stay due to hypercatabolism triggered by the stress response and the difficulty of optimising nutrition [1, 2]. In critically ill patients in the intensive care unit (ICU) who do not receive adequate nutritional support may lead to the loss of adipose and muscle tissue resulting in weight loss, impaired immune response, increased risk of infection, delayed wound healing, metabolic acidosis and respiratory dysfunction. These conditions can prolong the duration of hospital stay. Ultimately, a poor prognosis is likely to ensue [3].

Artificial nutritional support has become a primary therapeutic intervention to prevent metabolic derangement and the loss of lean body mass in these patients. Enteral feeding is generally considered more physiological, offering benefits in maintaining structural and functional gut integrity, as well as preserving gut microbial diversity [4]. Parenteral nutrition (PN) is the intravenous administration of all or part of the essential nutrients when enteral nutrition (EN) is not possible

due to anatomical or functional impairment of the gastrointestinal tract. PN can be lifesaving for patients who cannot receive oral or enteral nutrition. Additionally, initiating complementary PN within the first 4 days of hospitalisation in patients with inadequate EN has been shown to improve clinical outcomes [5, 6]. Parenteral nutrition (PN) can be administered as total parenteral nutrition (TPN) alone or as supplemental parenteral nutrition in combination with oral/enteral feeding. PN should not be used in patients with functional gastrointestinal systems. It is also contraindicated in patients with haemodynamic instability, uncontrolled hyperglycaemia, hyperosmolarity or hypervolemia. Additionally, PN is generally not recommended for patients with conditions such as end-stage cancer or dementia, where nutritional support is unlikely to provide benefit [7]. The former is a more costly treatment compared to the latter and can be associated with infectious and mechanical complications, as well as hyperglycaemia, hypertriglyceridaemia and electrolyte imbalances [8]. In recent years, significant advancements have reduced the complications associated with PN [9]. Although PN was previously considered problematic due to complications, advancements in its application have made it as safe as EN. Today, it is widely used in more patients [7]. This section presents a current assessment of parenteral nutrition, one of the nutritional strategies for patients in the intensive care unit.

European guidelines state that all critically ill patients who receive less than the targeted enteral nutrition after two days should be evaluated for supplemental parenteral nutrition (SPN) [6]. Although the cost implications of implementing this strategy remain unclear, numerous studies have been conducted on the subject. A cost analysis based on data from a study in Belgium (EPaNIC) regarding supplemental parenteral nutrition reported that initiating SPN early (on day two) compared to late SPN (on day eight) resulted in higher overall costs following admission to the intensive care unit [10]. Furthermore, despite the higher cost of PN containing omega-3 fatty acids compared to standard PN, it was associated with reduced hospitalisation duration and fewer infections, leading to overall cost reductions. This highlights the importance of considering not only the direct costs of nutrition but also the overall treatment costs when selecting a treatment option [11].

2. Parenteral nutrition administration methods

Parenteral nutrition should be administered through a central line due to its hypertonic nature. However, peripheral parenteral nutrition (PPN), which contains lower nutritional content and requires larger volumes, may be considered for patients for whom a suitable central line is not accessible and who are planned for short-term nutritional support.

2.1 Central TPN

A central venous catheter (CVC) is a device inserted into a large central vein (typically the internal jugular, subclavian or femoral vein) with the terminal lumen advancing into the inferior vena cava, superior vena cava or right atrium. In addition to direct central venous catheterisation, other methods of administration include subcutaneously tunnelled catheters (Hickman, Broviac, Groshong), catheters with subcutaneous ports and long central catheters inserted through peripheral veins. This allows for the direct infusion of high-osmolarity solutions into the circulation,

enabling the delivery of the patient's total caloric and protein requirements. However, complications related to central catheterisation may arise. The subclavian vein region is the site with the lowest risk of infectious and thrombotic complications [12]; thus, right subclavian catheterisation is considered the safest method, as left subclavian catheterisation may lead to complications such as thoracic duct injury.

2.2 Peripheral TPN

While peripheral catheters are suitable for administering a diluted nutrient mixture, they are prone to a higher rate of complications. However, patients can receive PPN for up to 14 days to address nutritional deficiencies or provide emergency nutritional support when a central venous catheter is not available as a temporary alternative to oral or enteral feeding [13, 14]. Due to common complications, such as thrombophlebitis and extravasation, longer-term use is not recommended. The compensatory capacity of the veins limits the use of the peripheral system for such infusions; therefore, most PPN formulations range from 750 to 900 mOsm/L [15]. Due to this hypo-osmolar content, PPN is not recommended for patients with fluid restrictions. Peripheral TPN can be applied in the following situations: when the patient is at high risk of a surgical stress response; to avoid invasive procedures; to support limited oral or enteral intake during the perioperative period, particularly on the first postoperative day; or when CVC-related complications occur [16, 17].

3. Indications for TPN

Gastrointestinal failure of varying degrees is frequently observed in critically ill patients, leading to enteral nutrition intolerance in approximately 60% of cases [18]. In these patients, EN is often interrupted, making it difficult to achieve adequate energy and protein intake [18, 19]. Situations in which EN is disrupted include intestinal failure caused by disease or treatment, high-output fistulas, severe bowel obstructions or an inaccessible gastrointestinal system. In such cases, TPN helps ensure safe and adequate energy and protein intake. The current evidence-based indications for TPN are presented in **Table 1** [20–22].

4. When should TPN be initiated?

In addition to determining which patients are suitable for parenteral nutrition, there are also conflicting recommendations regarding the timing of initiating nutrition. Internationally recognised guidelines, such as those from the American Society for Parenteral and Enteral Nutrition (ASPEN), the European Society for Clinical Nutrition and Metabolism (ESPEN) and the German Society for Nutritional Medicine (DGEM), generally agree that total parenteral nutrition should be initiated as soon as possible in patients at high nutritional risk. However, in patients with low nutritional risk, ASPEN does not recommend PN during the first 7 days, while ESPEN suggests adding PN within 3 to 7 days and DGEM does not provide a clear recommendation regarding the timing of PN initiation [6, 23, 24]. In cases of insufficient enteral nutrition, ASPEN recommends initiating supplemental PN after 7–10 days if more

Gastrointestinal Dysfunction	Haemodynamic Instability	Energy Deficiency
High-output GI fistula	Refractory shock	Failure to meet 60% of energy requirements for more than 4 to 5 days
Intestinal obstruction	High-dose vasopressor use	Total energy balance below 6000 kcal or protein deficit >300 g
Prolonged bowel rest		
Paralytic ileus		
Severe malnutrition when enteral nutrition is not feasible		
Severe abdominal sepsis		
Hyperemesis gravidarum		
Severe and persistent diarrhoea		
Malabsorption due to short bowel syndrome		

Table 1.
Current evidence-based indications for TPN [20–22].

than 60% of energy and protein requirements cannot be met, while other guidelines recommend case-by-case evaluation [23].

Every critically ill patient who remains in the ICU for more than 48 hours is at risk of malnutrition. While the optimal time to initiate supplemental PN to fully meet energy requirements has not been definitively established, it is generally recommended to start within 5 to 7 days [7]. However, in malnourished patients where oral or enteral nutrition is either insufficient or unavailable, it is recommended to initiate PN as soon as possible [9]. When initiating PN, the dose on the first day should not exceed 50% of the target energy requirement and the patient should be closely monitored while gradually increasing the dose. Depending on the patient's comorbidities, underlying disease and critical condition, the target dose is typically reached within 3 to 7 days. In most cases, it is expected that haemodynamically stable and non-critical patients will reach the target by the third day. PN should be gradually reduced and discontinued over 2 to 3 days once enteral and/or oral routes meet 60% of the target energy level [7].

In recent years, significant advances in PN formulations and improvements in preparation processes have reduced PN-related complications. Today, parenteral nutrition products are commercially available in various types and forms. These include two-in-one solutions containing proteins (amino acids, AAs) and carbohydrates (CHO), as well as three-in-one solutions that also contain lipids. Some of these products are supplied in pre-filled bags with two or three separate compartments designed for mixing prior to use [25]. There are two options for this compounding process: hospital pharmacy compounded bags (HPCBs) and commercially available multi-chamber bags (MCBs). HPCBs must be prepared daily by the pharmacy due to their limited stability, especially when tailored PN is required to meet the individual needs of critically ill patients, necessitating special equipment and infrastructure. In contrast, MCBs contain a fixed amount of macronutrients, with or without electrolytes, housed in separate compartments within a single bag. The nutrients are mixed by breaking the plastic seals between the compartments during preparation. Most MCBs on the market have a shelf life of more than 24 months at room temperature [26].

5. TPN complications

Total parenteral nutrition (TPN) is beneficial and life-saving in various clinical situations but can also lead to numerous serious side effects. The risk of such complications can be minimised through the careful monitoring of patients and with the assistance of nutrition support teams. PN complications can be categorised as mechanical, infectious or metabolic.

5.1 Mechanical complications

Pneumothorax, air embolism, haemorrhage, venous thrombosis and vascular injury are some of the possible catheter-related complications [12]. Careful intervention under aseptic conditions by trained operators, preferably with ultrasound (US) guidance, minimises mechanical complications.

5.2 Infectious complications

In addition to procedure-related complications, catheter-related infectious complications, such as central line-associated bloodstream infections (CLABSI) and local skin infections at the insertion or exit site, must be carefully monitored [27, 28]. CLABSIs are a significant complication as they can increase morbidity, mortality, length of hospital stay and healthcare costs; therefore, strict adherence to aseptic protocols is essential. Guidelines exist for the prevention of CLABSI. Minimising these complications involves ensuring adequate training for healthcare professionals who insert and maintain catheters, enhancing adherence to hygiene protocols, using ultrasound guidance for catheter placement and employing antiseptic barrier caps, needleless safety devices and antimicrobial- or antiseptic-impregnated catheters [15, 29]. In addition to central line infections, PN increases the general risk of infections, including pneumonia and intra-abdominal abscesses [30].

5.3 Metabolic complications

Metabolic complications are more common in patients receiving PN compared to those receiving EN, which is why close monitoring is required to prevent and detect complications early. Renal function, liver tests, glycaemia and serum electrolyte and triglyceride levels should be monitored daily until stable and then at least weekly (more frequently in critically ill patients or those at risk of refeeding syndrome). Hyperglycaemia is the most common complication of PN, occurring in approximately 50% of patients. It is often due to overfeeding during the acute phase of insulin resistance or underlying subclinical diabetes. Other factors that may trigger hyperglycaemia include age over 65, underlying diabetes, the presence of infection, renal failure and the concurrent use of glucose-raising medications (e.g., glucocorticoids, tacrolimus, somatostatin or octreotide). Some studies have shown that strict glycaemic control below 110 mg/dL reduces mortality and morbidity in critically ill patients [31]. However, recent data suggest that glucose levels up to 180 mg/dL (10 mmol/L) are acceptable for avoiding life-threatening hypoglycaemia [1, 32]. Blood glucose levels above 200 mg/dL are not recommended, as they may trigger dehydration and polyuria. The presence of hyperlactataemia is another prognostic factor in glucose control. Glucose and lactate are linked through the Cori cycle as part of glycolysis and gluconeogenesis. Some studies have shown a significant increase in mortality when

hyperglycaemia and hyperlactataemia occur simultaneously [33, 34]. Patients should be treated with insulin infusions to maintain normal glucose levels and reduce the risk of sepsis [31]. Although hypoglycaemia is less common than hyperglycaemia, patients, particularly those on insulin infusions, should be closely monitored for this complication. Hypertriglyceridaemia is another common metabolic complication associated with PN, occurring in approximately 25–50% of patients. Studies have shown that the degree of hypertriglyceridaemia is influenced not only by the dosage of intravenous lipids but also by various other factors (e.g. sepsis, renal failure, hyperglycaemia, obesity, alcoholism, pancreatitis, high-output fistula, multiple organ failure, pre-existing hyperlipidaemia and the use of corticosteroids, cyclosporine, tacrolimus, sirolimus or propofol) [23, 35]. During continuous lipid infusion, serum triglyceride levels should not exceed 400 mg/dL [1]. Fish oil-containing formulations have been proposed as a means to accelerate lipid clearance and reduce the risk of hypertriglyceridaemia while maintaining energy intake [36]. If metabolic control cannot be achieved within a few days, reversible hepatic steatosis or acute pancreatitis due to hypertriglyceridaemia may develop.

Hepatic complications occur in 15–40% of patients receiving PN. These patients often test positive for abnormal liver function, although most of these abnormalities are related to underlying disease, medications or sepsis, among other conditions, rather than PN itself. PN-associated liver disease (PNALD) is a spectrum of conditions that ranges from mild liver enzyme abnormalities to steatosis and eventually fibrosis or cirrhosis [23, 37]. Among these, PN-associated steatosis is the most common and typically occurs within 2 weeks of starting PN, often caused by excessive carbohydrate or lipid intake [37]. Another hypothesis suggests that the combination of omega-6 and phytosterols in soybean-based formulations increases the risk of hepatic complications [38]. Modifying PN composition and avoiding excessive energy intake are important strategies to reduce the risk of PNALD. In particular, in patients with cholestasis, the early introduction of enteral feeding to stimulate the intestines has been shown to be beneficial in preventing pathologies, such as bile sludging [39, 40]. Recent studies have also reported improvements in cholestasis with ursodeoxycholic acid [41]. Since most hepatic complications are related to sepsis and infection, preventing and managing infections is also recommended.

Refeeding syndrome (RS) can be defined as significant shifts in fluids and electrolytes that occur in malnourished patients receiving nutrition, whether enteral or parenteral [42]. Although its exact incidence is unclear, studies estimate that it affects 20–30% of the population [43]. When in a state of malnutrition, the body conserves energy by affecting membrane pumps, causing intracellular leakage of K, Mg, Ca and PO_4, followed by depletion throughout the body. Refeeding reverses this process, leading to a rapid decrease in circulating K, Mg, Ca and PO_4 as these electrolytes are driven into cells by insulin. Phosphorus is the most sensitive electrolyte in this process [44, 45]. Additionally, thiamine deficiency has been described in RS. Severe cases of these electrolyte imbalances can manifest as heart failure, arrhythmias, seizures, comas, respiratory failure and muscle weakness. Therefore, patients at risk of RS should be screened before starting nutrition and monitored closely. ASPEN considers patients who fulfil any of the following criteria to be at moderate to high risk of RS: those with a BMI < 18.5 kg/m^2; those who have lost more than 5% of their body weight in the past month or 7.5–10% in the past 3 to 6 months; those with little or no oral intake for more than 5 to 6 days; those whose calorie intake during acute illness or injury is estimated to be less than 75% for more than 5 days; those with abnormal

Mechanical complications	Infectious complications	Metabolic complications
Pneumothorax	Central line-associated bloodstream infection	Hyperglycaemia
Hydrothorax/haemothorax	Pneumonia	Hypertriglyceridaemia
Air embolism	Intra-abdominal abscess	Hepatic complications
Cardiac tamponade		Refeeding syndrome
Chylothorax		Metabolic bone disease
Venous thrombosis		Intestinal mucosal atrophy

Table 2.
Current complications associated with TPN in ICU patients.

potassium, phosphorus or magnesium serum concentrations; those who experience subcutaneous fat and muscle mass loss; and those with comorbidities, such as alcoholism, eating disorders, cancer or malabsorptive conditions [38]. These patients should begin with low-calorie intake (in severe cases, 10–20 kcal/kg/day or less) and gradually increase their intake over 4 to 7 days to meet their needs [44, 45].

Another complication related to PN use is metabolic bone disease, particularly in patients receiving long-term PN. Although the exact incidence is unclear, it has been detected in about 40% of patients undergoing long-term treatment. Bone changes are likely related to suboptimal calcium, phosphate and vitamin D intake, lack of physical activity, low vitamin D status due to insufficient sunlight exposure and the side effects of other treatments (e.g. heparin, steroids) [46].

Finally, gastrointestinal side effects (mucosal atrophy, increased translocation of microorganisms and their toxins) may also occur. The complications seen in critically ill patients are summarised in **Table 2**.

6. Parenteral nutrition components

PN contains amino acids, dextrose and lipids to meet calorie and protein requirements. The proportions of these macronutrients should be adjusted according to the patient's weight and comorbidities and the risk of refeeding syndrome (RS). Micronutrients, such as electrolytes, vitamins and trace elements, can also be administered as part of the patient's nutrition. These micronutrients should be tailored to the individual patient based on an assessment of their electrolyte levels, renal and liver function and fluid status. Historically, these components were prepared and administered in separate solutions. However, today, all-in-one (three-in-one) mixture systems for parenteral nutrition are widely available. The total nutrient admixture (TNA), which combines all components of PN into a single solution, has been found to be safe and well tolerated [47]. Additionally, this method reduces the number of intravenous interventions, thereby lowering the risk of infection [47, 48].

The intravenous access route in parenteral administration is another factor that can influence the PN composition. For patients receiving PPN, the total volume must be increased, and the concentration of macronutrients must be reduced to lower the osmolarity. It is advised that the macronutrient content in PPN should include less than 4% amino acids and less than 10% glucose [49]. Since lipids have low osmolarity, products with high lipid content should be used to achieve the target

caloric intake. To ensure the effective and appropriate administration of a parenteral product, the factors influencing its stability must also be understood. It is known that calcium phosphate precipitates can form at high temperatures and low pH, while exposure to light and oxygen can lead to amino acid degradation and vitamin instability [32, 49, 50].

6.1 Protein content

Both essential and non-essential amino acids are crucial components of parenteral nutrition as they support cell, organ, skeletal, cardiac and respiratory muscle functions, as well as wound healing [23, 51]. In critically ill patients, it has been demonstrated that their amino acid profile is disturbed, lean body mass is lost and amino acid supplementation is required due to increased catabolic processes [6, 23]. These amino acids include essential ones that cannot be synthesised in the body—histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine—as well as arginine, which can be synthesised in small amounts, and alanine, asparagine, aspartate, glutamate, glutamine, glycine, proline and serine, which can be synthesised fully. Standard amino acid solutions contain all nine essential amino acids, sufficient non-essential amino acids to support their synthesis, adequate nitrogen and arginine to meet or exceed recommended dietary allowances. Protein needs in patients receiving PN are met with intravenous free amino acid solutions, which also provide 4 kcal/g of energy [23, 52]. Since peptide bond formation is a dehydration reaction, amino acids provide less energy and substrate than the proteins they form [52]. In protein formation, in addition to the nitrogen content provided by amino acids (16%), a sufficient protein substrate is also required. According to ASPEN guidelines, the optimal non-protein-calorie-to-nitrogen ratio in critically ill patients ranges from 70:1 to 100:1, which decreases to 30:1 to 50:1 in obese patients [23].

Currently, guidelines recommend a protein target of 1.0–2 g/kg/day, and increased protein intake has been associated with improved long-term physical recovery and lower mortality in observational studies [6, 23, 53]. Achieving high-protein intake is easier with parenteral nutrition than with enteral nutrition. In studies, protein intake with enteral nutrition has not exceeded 1.5 g/kg/day [54].

6.2 Carbohydrate content

The most commonly used carbohydrate substrate is dextrose, which provides 3.4 kcal/g of carbohydrates in its hydrated form and 4 kcal/g in its anhydrous form, which is used in some regions. Approximately 60% of non-protein energy should come from carbohydrates, and the upper supply limit is 4 g/kg body weight/day (2.8 mg/kg/min). A preferred intake is between 3.0 and 3.5 g/kg body weight/day (2.1–2.4 mg/kg body weight/min). Since intravenous dextrose bypasses the entero-insular axis, it leads to a more pronounced increase in blood glucose levels compared to the same amount administered enterally. For this reason, patients receiving parenteral nutrition are at a higher risk for hyperglycaemia. Continuous dextrose infusion rates in these patients should be kept at ≤4–7 mg/kg/min [23, 55]. In the case of hyperglycaemia, patients should be placed under strict glycaemic monitoring with intravenous insulin therapy, and carbohydrate intake should be stopped in those with persistent hyperglycaemia requiring more than 6 IU/hour of insulin [55].

6.3 Lipid content

Intravenous lipid emulsions (IVLEs) are a source of essential fatty acids (EFAs) and non-protein calories. They are important because they reduce reliance on glucose for non-protein energy. Fatty acids form the main components of cellular biomembranes, contributing to membrane integrity, regulating permeability and serving as precursors for essential modulators in cellular pathways of the immune system [56]. Therefore, they are vital to biological functions in the body. Lipids provide 20–30% of daily total calories. To prevent lipid overload, guidelines recommend that IVLE doses should not exceed 1 g/kg/day based on body weight. Maximum doses for IVLEs are 2.5 g/kg body weight/day for soy-based IVLEs, 2 g/kg/day for olive oil-based IVLEs and 2 g/kg/day for fish oil-based IVLEs [57]. If a patient's triglyceride level exceeds 3 mmol/L (265 mg/dL), fish oil-based IVLEs should be discontinued. Furthermore, if triglyceride levels exceed 4.5 mmol/L, soy-based and olive oil-based IVLEs should be reduced or discontinued [57]. Intravenous fats bypass the intestinal lumen, are not hydrolysed by pancreatic lipases and are not emulsified by bile. Therefore, IV lipids must be prepackaged to enable their transfer into the hydrophilic physiological environment [23, 58].

6.4 Micronutrient content

Electrolyte and fluid requirements in critically ill patients vary depending on their renal function, fluid and electrolyte status and underlying diseases and losses [23, 55]. Current parenteral nutrition solutions do not contain vitamins or trace elements. These should be added to the solutions based on the patient's current values. According to current guidelines, vitamins and trace elements should be administered daily and routinely added to PN solutions unless there is a risk of overload. High doses of micronutrients should not be given without a proven deficiency [6].

7. Nutrition in special conditions

Specialised nutrition strategies are crucial for patients in intensive care. Nutritional support should be initiated based on the patient's BMI, comorbidities and haemodynamic status, requiring a patient-specific assessment to reduce PN-related complications and improve clinical outcomes.

7.1 Malnourished patients

Malnutrition is defined as a condition of insufficient intake or absorption of nutrients, leading to changes in body composition. Awareness of the adverse effects of malnutrition, particularly in patients with multiple comorbidities, has increased due to the high number of malnourished patients in hospitals. Early hypocaloric PN, with a target of 75% of calories from protein, is recommended for patients with malnutrition who cannot be fed enterally [24]. Since malnourished patients are prone to complications such as metabolic intolerance, refeeding syndrome and increased infection rates, aggressive feeding strategies and high-calorie targets are not recommended [6, 59].

7.2 Obese patients

Obese patients require close monitoring in intensive care units because they are prone to muscle mass loss. Contrary to popular belief, they do not have adequate reserves and are vulnerable to malnutrition. Proper nutritional strategies should be implemented, especially to address complications associated with metabolic syndrome, which often accompanies obesity. A high-protein, hypocaloric diet would be appropriate for preventing muscle catabolism, improving body composition and avoiding insulin resistance and hyperglycaemia in obese patients [6].

7.3 Elderly patients

In elderly patients, energy requirements often decrease due to a reduction in metabolic rate. This decrease becomes more pronounced with advancing age, and it is thought to be around 5% per decade after the age of 50. In this group, the incidence of malnutrition, sarcopenia and cachexia is higher due to the loss of lean body mass [59]. Therefore, guidelines suggest that adequate macronutrient support can reduce complications in these patients and recommend hypercaloric and high-protein targets (30 kcal/kg/day for energy and > 1 g/kg/day for protein) [6, 23]. Close monitoring is also recommended for micronutrient needs [6].

7.4 Shock

For ICU patients in shock, the addition of and complete reliance on PN in the acute phase should be evaluated separately. Guidelines are in agreement that PN should not be administered to septic patients unless haemodynamic stability is achieved [58–60]. However, ESPEN guidelines recommend complementary parenteral nutrition after the third day in patients who can tolerate enteral feeding, while ASPEN advises against total parenteral nutrition in the acute phase due to limited substrate utilisation. In patients requiring PN, normocaloric intake should be targeted, and physiological doses of vitamins and trace elements should be added to parenteral solutions due to increased needs.

7.5 Central nervous system disease

In patients with central nervous system (CNS) diseases (e.g. head trauma, haemorrhagic or ischemic stroke), the indication for parenteral nutrition typically arises in cases in which adequate enteral nutrition cannot be achieved or in the presence of comorbidities, such as shock or haemodynamic instability. Outside of these situations, enteral nutrition is recommended for this patient population, and there is no direct indication for PN related to CNS conditions. However, this patient group may require long-term hospitalisation, and attention should be given to preventing malnutrition, considering complementary parenteral nutrition if necessary.

7.6 Cardiac disease

In patients with heart failure, malnutrition, cachexia and sarcopenia are common conditions. Due to fluctuations in fluid status, it is recommended to use energy-dense formulas with fluid restriction [23]. Although limited evidence exists, complementary PN is considered safe in this patient group. However, administration must

be done via a central venous catheter, as peripheral administration could lead to increased fluid volume, which is inappropriate for these patients.

7.7 Respiratory diseases

In patients with respiratory failure, guidelines recommend the use of PN in cases of life-threatening hypoxia, hypercapnia or respiratory decompensation [6, 23, 24]. Formulas with high fat and low carbohydrate content are suggested to reduce the respiratory quotient and to lessen carbon dioxide production. However, since lipogenesis can also increase CO_2 production, hyperalimentation should be avoided.

7.8 Acute pancreatitis

According to ESPEN guidelines, patients with acute pancreatitis (AP) are considered to have moderate to high nutritional risk due to the catabolic nature of the disease and the impact of nutritional status on disease progression [61]. Parenteral nutrition may be indicated in these patients due to severe complications, such as intestinal obstruction, abdominal compartment syndrome, prolonged paralytic ileus and mesenteric ischemia. Given that AP is a risk factor for hyperglycaemia and hypertriglyceridaemia, it is recommended to closely monitor blood glucose and triglyceride levels and adjust the nutritional content accordingly. ESPEN guidelines also recommend the use of parenteral glutamine in addition to PN [18]. Additionally, omega-3 fatty acids, particularly when administered parenterally, have been shown to reduce mortality, infectious complications and hospital stay length in AP patients [62].

7.9 Surgical patients

ESPEN guidelines on clinical nutrition in surgery recommend complementary PN if the patient fails to meet 50% of the required values for over 7 days through oral and enteral intake [63]. Indications for TPN in postoperative patients include surgical complications, such as prolonged paralytic ileus, leakage or disruption of anastomoses and high-output fistulas. Studies also support that supplementation with glutamine and omega-3 fatty acids reduces mortality and infectious complications in these patients [64].

8. Patient monitoring

Metabolic complications are more common in patients receiving PN compared to those receiving EN. Therefore, close monitoring is essential for the prevention and early detection of complications. If metabolic abnormalities are detected or if the patient is at risk for refeeding syndrome, frequent monitoring is required. Preventing refeeding syndrome is critical and can be achieved through a slower-than-usual initial TPN infusion rate [65]. According to ASPEN guidelines, patients who are critically ill and unstable should be monitored daily until their condition stabilises. Stable patients who have not undergone any formulation changes for a week should be monitored every 2 to 7 days, while patients in long-term care settings, who remain clinically stable and have had no formulation changes for a week, should be monitored every 1 to 4 weeks [66].

9. Conclusion

Malnutrition is a common and significant issue among patients in the ICU. Hence, patients admitted to the ICU should be evaluated for the risk of malnutrition, their nutritional needs should be identified and appropriate nutritional support should be initiated within the first 24 hours. However, in clinical practice, assessing the nutritional status of patients is often neglected. Unless timely and adequate nutrition support is provided, energy and protein deficits may occur. Recognising malnutrition and initiating appropriate nutritional therapy can reduce morbidity and mortality. Nutritional support in ICU patients is typically provided through enteral and parenteral nutrition. While the former is always the preferred option, the latter enables feeding in patients who cannot be fed enterally. When used appropriately, early parenteral nutrition can positively impact the clinical course of patients. Nevertheless, it may also result in infectious, metabolic and catheter-related complications. To prevent these potential complications, close clinical and laboratory monitoring is essential.

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References

[1] Hartl WH, Jauch KW. Metabolic self-destruction in critically ill patients: Origins, mechanisms and therapeutic principles. Nutrition. 2014;**30**:261-267. DOI: 10.1016/j.nut.2013.07.019

[2] Wade CE, Kozar RA, Dyer CB, Bulger EM, Mourtzakis M, Heyland DK. Evaluation of nutrition deficits in adult and elderly trauma patients. Journal of Parenteral and Enteral Nutrition. 2014;**39**:449-455

[3] Çekmen N, Dikmen E. Enteral and parenteral nutrition in intensive care medicine. Bulletin of Thoracic Surgery. 2014;**5**(3):187-197

[4] Barrett M, Demehri FR, Teitelbaum DH. Intestine, immunity, and parenteral nutrition in an era of preferred enteral feeding. Current Opinion in Clinical Nutrition and Metabolic Care. 2015;**18**:496-500. DOI: 10.1097/MCO.0000000000000208

[5] Heidegger CP, Berger MM, Graf S, Zingg W, Darmon P, Costanza MC, et al. Optimisation of energy provision with supplemental parenteral nutrition in critically ill patients: A randomised controlled clinical trial. Lancet. 2013;**381**(9864):385-393

[6] Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, Casaer MP, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clinical Nutrition. 2019;**38**:48-79. DOI: 10.1016/j.clnu.2018.08.037

[7] Kahveci FS, Demirkan K, Doğanay M, Gömceli I, Gündoğan K, Topeli A, et al. Parenteral nutrition consensus report from KEPAN. Nutrition. 2024;**123**:112424. DOI: 10.1016/j.nut.2024.112424

[8] Ayers P, Adams S, Boullata J, Gervasio J, Holcombe B, Kraft MD, et al. Parenteral nutrition safety consensus recommendations. Journal of Parenteral and Enteral Nutrition. 2014;**38**:296-333. DOI: 10.1177/0148607113511992

[9] Berlana D. Parenteral Nutrition Overview. Nutrients. 2022;**14**(21):4480. DOI: 10.3390/nu14214480

[10] Casaer MP, Mesotten D, Hermans G, Wouters PJ, Schetz M, Meyfroidt G, et al. Early versus late parenteral nutrition in critically ill adults. 11 Aug 2011;**365**(6):506-517

[11] Xie H, Chang YN. Omega-3 polyunsaturated fatty acids in the prevention of postoperative complications in colorectal cancer: A meta-analysis. Oncotargets and Therapy. 2016;**9**:7435-7443

[12] Parienti JJ, Mongardon N, Mégarbane B, Mira JP, Kalfon P, Gros A, et al. 3SITES study group. Intravascular complications of central venous catheterization by insertion site. The New England Journal of Medicine. 2015;**373**(13):1220-1229

[13] Weimann A, Braga M, Carli F, Higashiguchi T, Hubner M, Klek S, et al. ESPEN guideline: Clinical nutrition in surgery. Clinical Nutrition. 2017;**36**:623-650

[14] Culebras JM, Martin-Pena G, Garcia-de-Lorenzo A, Zarazaga A, Rodriguez-Montes JA. Practical aspects of peripheral parenteral nutrition. Current Opinion in Clinical Nutrition and Metabolic Care. 2004;**7**:303-307

[15] Senkal M, Bonavina L, Reith B, Caruso R, Matern U, Duran M. Perioperative peripheral parenteral

nutrition to support major gastrointestinal surgery: Expert opinion on treating the right patients at the right time. Clinical Nutrition ESPEN. 2021;**43**:16-24. DOI: 10.1016/j.clnesp.2021.04.006

[16] Liu M-Y, Tang H-C, Yang H-L, Huang H-H, Chang S-J. Hypo-calories with micronutrients and fat emulsion of pre-operative peripheral parenteral nutrition in malnutrition risk rectal cancer patients: A retrospective cross-sectional study. Food and Nutrition Sciences. 2013;**4**:821

[17] Jin Y, Yong C, Ren K, Li D, Yuan H. Effects of post-surgical parenteral nutrition on patients with gastric cancer. Cellular Physiology and Biochemistry. 2018;**49**:1320-1328

[18] Reintam A, Parm P, Kitus R, Starkopf J, Kern H. Gastrointestinal failure score in critically ill patients: A prospective observational study. Critical Care. 2008;**12**(4):R90. DOI: 10.1186/cc6958

[19] Blaser AR, Rice TW, Deane AM. Update on nutritional assessment and therapy in critical care. Current Opinion in Critical Care. 2020;**26**(2):197-204. DOI: 10.1097/MCC.0000000000000694

[20] Pironi L, Arends J, Bozzetti F, Cuerda C, Gillanders L, Jeppesen PB, et al. ESPEN guidelines on chronic intestinal failure in adults. Clinical Nutrition. 2016;**35**(2):247-307. DOI: 10.1016/j.clnu.2016.01.020

[21] Cuerda C, Pironi L, Arends J, Bozzetti F, Gillanders L, Jeppesen PB, et al. ESPEN practical guideline: Clinical nutrition in chronic intestinal failure. Clinical Nutrition. 2021;**40**:5196-5220. DOI: 10.1016/j.clnu.2021.07.002

[22] Mueller CM. The ASPEN Nutrition Support Core Curriculum. 3rd ed. Silver Spring, MD, USA: American Society of Parenteral and Enteral Nutrition; 2017

[23] 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.). Journal of Parenteral and Enteral Nutrition. 2016;**40**:159-211. DOI: 10.1177/0148607115621863

[24] Elke G, Hartl WH, Kreymann KG, Adolph M, Felbinger TW, Graf T, et al. Clinical nutrition in critical care medicine—Guideline of the German Society for Nutritional Medicine (DGEM). Clinical Nutrition ESPEN. 2019;**33**:220-275. DOI: 10.1016/j.clnesp.2019.05.002

[25] Slattery E, et al. 3-in-1 vs 2-in-1 parenteral nutrition in adults

[26] Alfonso JE, Berlana D, Ukleja A, Boullata J. Clinical, ergonomic, and economic outcomes with multichamber bags compared with (hospital) pharmacy compounded bags and multibottle systems: A systematic literature review. Journal of Parenteral and Enteral Nutrition. 2017;**41**:1162-1177. DOI: 10.1177/0148607116657541

[27] Martincich I, Cini K, Lapkin S, Lord H, Fernandez R. Central venous access device complications in patients receiving parenteral nutrition in general Ward settings: A retrospective analysis. Journal of Parenteral and Enteral Nutrition. 2020;**44**:1104-1111. DOI: 10.1002/jpen.1743

[28] Latif A, Halim MS, Pronovost PJ. Eliminating infections in the ICU:

CLABSI. Current Infectious Disease Reports. 2015;**17**(7):491

[29] Mermel LA, Farr BM, Sheretz RJ, et al. Infectious Diseases Society of America, American College of Critical Care Medicine, Society for Healthcare Epidemiology of America. Guidelines for the management of intravascular catheter-related infections. Clinical Infectious Diseases. 2001;**32**:1249-1272

[30] Elhassan AO, Tran LB, Kaye AD. Total parenteral and enteral nutrition in the ICU. Evolving concept. Anesthesiology Clinics. 2017;**35**:181-190. DOI: 10.1016/j.anclin.2017.01.004

[31] Van den Berghe G, Wouters P, Weekers F, Verwaest C, Bruyninckx F, Schetz M, et al. Intensive insulin therapy in critically ill patients. The New England Journal of Medicine. 2001;**345**:1359-1367. DOI: 10.1056/NEJMoa011300

[32] Pertkiewicz M, Cosslett A, Mühlebach S, Dudrick SJ. Basics in clinical nutrition: Stability of parenteral nutrition admixtures. e-SPEN the European e-Journal of Clinical Nutrition and Metabolism. 2009;**4**:e117-e119. DOI: 10.1016/j.eclnm.2009.01.010

[33] Green JP, Berger T, Panacek EA. Hyperlactatemia affect the association of hyperglycemia with mortality in non-diabetic adults with sepsis. Academic Emergency Medicine. 2012;**19**:1268-1275. DOI: 10.1111/acem.12015

[34] Jorge PF, Wieringa N, Nijsten MW. The association of early combined lactate and glucose levels with subsequent renal and liver dysfunction and hospital mortality in critically ill patients. Critical Care Medicine. 2017;**21**:218

[35] Llop J, Sabin P, Garau M, Burgos R, Pérez M, Massó J, et al. The importance of clinical factors in parenteral nutrition-associated hypertriglyceridemia. Clinical Nutrition. 2003;**22**:577-583. DOI: 10.1016/S0261-5614(03)00082-7

[36] Mateu-de AJ, Florit-Sureda M. New strategy to reduce hypertriglyceridemia during parenteral nutrition while maintaining energy intake. Journal of Parenteral and Enteral Nutrition. 2016;**40**:705-712. DOI: 10.1177/0148607114549253

[37] Madnawat H, Welu AL, Gilbert EJ, Taylor DB, Jain S, Manithody C, et al. Mechanisms of parenteral nutrition-associated liver and gut injury. Nutrition in Clinical Practice. 2020;**35**:63-71. DOI: 10.1002/ncp.10461

[38] Calder PC, Waitzberg DL, Klek S, Martindale RG. Lipids in parenteral nutrition: Biological aspects. Journal of Parenteral and Enteral Nutrition. 2020;**44**:S21-S27. DOI: 10.1002/jpen.1756

[39] Lloyd DA, Gabe SM. Managing liver dysfunction in parenteral nutrition. The Proceedings of the Nutrition Society. 2007;**66**:530-538

[40] Arenas Villafranca JJ, Nieto GM, Álvaro SE, Moreno SM, Garrido SM, Abilés J. Effects of cyclic parenteral nutrition on parenteral-associated liver dysfunction parameters. Nutrition Journal. 2017;**16**:66. DOI: 10.1186/s12937-017-0289-7

[41] San Luis VA, Btaiche IF. Ursodiol in patients with parenteral nutrition-associated cholestasis. The Annals of Pharmacotherapy. 2007;**41**(11):1867-1872. DOI: 10.1345/aph.1K229. Epub 2007 Oct 2

[42] Solomon SM, Kirby DF. Yeniden beslenme sendromu: Bir inceleme. Journal of Parenteral and Enteral Nutrition. 1990;**14**:90-97. DOI: 10.1177/014860719001400190

[43] Koekkoek WAC, Van Zanten ARH. Is refeeding syndrome relevant for critically ill patients? Current Opinion in Clinical Nutrition and Metabolic Care. 2018;**21**(2):130-137. DOI: 10.1097/MCO.0000000000000449

[44] Da Silva JS, Seres DS, Sabino K, Adams SC, Berdahl GJ, Citty SW, et al. ASPEN consensus recommendations for refeeding syndrome. Nutrition in Clinical Practice. 2020;**35**:178-195. DOI: 10.1002/ncp.10474

[45] Friedli N, Stanga Z, Sobotka L, Culkin A, Kondrup J, Laviano A, et al. Revisiting the refeeding syndrome: Results of a systematic review. Nutrition. 2017;**35**:151-160. DOI: 10.1016/j.nut.2016.05.016

[46] Cohen-Solal M, Baudoin C, Joly F, Vahedi K, D'Aoust L, De Vernejoul MC, et al. Osteoporosis in patients on long-term home parenteral nutrition: A longitudinal study. Journal of Bone and Mineral Research. 2003;**18**(11):1989-1994. DOI: 10.1359/jbmr.2003.18.11.1989

[47] Campos AC, Paluzzi M, Meguid MM. Clinical use of total nutritional admixtures. Nutrition. 1990;**6**:347-356

[48] Emilio AJ, Berlana D, Boullata J. Clinical, ergonomic and economic outcomes with multichamber bags compared with (hospital) pharmacy compounded bags and multibottle systems: A systemic literature review. Journal of Parenteral and Enteral Nutrition. 2017;**41**:1162-1177. DOI: 10.1177/0148607116657541

[49] Mirtallo J, Canada T, Johnson D, Kumpf V, Petersen C, Sacks G, et al. Safe practices for parenteral nutrition. Journal of Parenteral and Enteral Nutrition. 2004;**28**:S39-S70. DOI: 10.1177/01486071040280S601

[50] Ferguson TI, Emery S, Price-Davies R, Cosslett AG. A review of stability issues associated with vitamins in parenteral nutrition. e-SPEN Journal. 2014;**9**:e49-e53. DOI: 10.1016/j.clnme.2014.01.001

[51] Ziegler TR. Parenteral nutrition in the critically ill patient. The New England Journal of Medicine. 2009;**361**:1088-1097

[52] Hoffer LJ. How much protein do parenteral amino acid mixtures provide? The American Journal of Clinical Nutrition. 2011;**94**:1396-1398. DOI: 10.3945/ajcn.111.023390

[53] Alberda C, Gramlich L, Jones N, Jeejeebhoy K, Day AG, Dhaliwal R, et al. The relationship between nutritional intake and clinical outcomes in critically ill patients: Results of an international multicenter observational study. Intensive Care Medicine. 2009;**35**:1728-1737. DOI: 10.1007/s00134-009-1567-4

[54] van Zanten ARH, Petit L, De Waele J, Kieft H, de Wilde J, van Horssen P, et al. Very high intact-protein formula successfully provides protein intake according to nutritional recommendations in overweight critically ill patients: A double-blind randomized trial. Critical Care. 2018;**22**:1-12. DOI: 10.1186/s13054-018-2070-5

[55] Boullata JI, Gilbert K, Sacks G, Labossiere RJ, Crill C, Goday P, et al. Clinical guidelines: Parenteral nutrition ordering, order review, compounding, Labeling, and dispensing. Journal of Parenteral and Enteral Nutrition. 2014;**38**:334-377. DOI: 10.1177/0148607114521833

[56] Carpentier YA, Dupont IE. Advances in intravenous lipid emulsions. World Journal of Surgery. 2000;**24**:1493-1497. DOI: 10.1007/s002680010267

[57] Gramlich L, Atkins M. Alberta Health Services Nutrition Practice Guidelines–Intravenous Lipid Emulsions. 14 Apr 2017;**9**(4):388. DOI: 10.3390/nu9040388. Unpublished Work

[58] Visschers RGJ, Olde Damink SWM, Gehlen JMLG, Winkens B, Soeters PB, van Gemert WG. Treatment of hypertriglyceridemia in patients receiving parenteral nutrition. Journal of Parenteral and Enteral Nutrition. 2011;**35**:610-615. DOI: 10.1177/0148607110389616

[59] Felder S, Lechtenboehmer C, Bally M, et al. Association of nutritional risk and adverse medical outcomes across different medical inpatient populations. Nutrition. 2015;**31**(11-12):1385-1393. DOI: 10.1016/j.nut.2015.06.007

[60] Anker SD, Laviano A, Filippatos G, John M, Paccagnella A, Ponikowski P, et al. ESPEN ESPEN guidelines on parenteral nutrition: On cardiology and pneumology. Aug 2009;**28**(4):455-460. DOI: 10.1016/j.clnu.2009.04.023

[61] Arvanitakis M, Ockenga J, Bezmarevic M, Gianotti L, Krznarić Ž, Lobo DN, et al. ESPEN guideline on clinical nutrition in acute and chronic pancreatitis. Clinical Nutrition. 2020;**39**:612-631. DOI: 10.1016/j.clnu.2020.01.004

[62] Lei Q, Wang X, Xia X, Zheng H, Bi J, Tian F, et al. The role of Omega-3 fatty acids in acute pancreatitis: A meta-analysis of randomized controlled trials. Nutrients. 2015;**7**:2261-2273. DOI: 10.3390/nu7042261

[63] Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M, Klek S, et al. ESPEN practical guideline: Clinical nutrition in surgery. Clinical Nutrition. 2021;**40**:4745-4761. DOI: 10.1016/j.clnu.2021.03.031

[64] Ziegler TR, May AK, Hebbar G, Easley KA, Griffith DP, Dave N, et al. Efficacy and safety of glutamine-supplemented parenteral nutrition in surgical ICU patients. Annals of Surgery. 2016;**263**:646-655. DOI: 10.1097/SLA.0000000000001487

[65] Lakananurak N, Gramlich L. The role of preoperative parenteral nutrition. Nutrients. 6 May 2020;**12**(5):1320. DOI: 10.3390/nu12051320

[66] Ayers P, Adams S, Boullata J, Gervasio J, Holcombe B, Kraft MD, et al. American Society for Parenteral and Enteral Nutrition. A.S.P.E.N. Parenteral nutrition safety consensus recommendations. JPEN Journal of Parenteral and Enteral Nutrition. 2014;**38**(3):296-333

Chapter 5

Nutritional Approach in Critically Ill Obese Patients

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Abstract

The term "critically ill obese patients" refers specifically to patients suffering from obesity, a condition that complicates treatment and follow-up in the intensive care unit (ICU), referring to a body mass index (BMI) of >30 kg/m^2. This is the result of a mixture of genetic, environmental, psychological and lifestyle factors associated with adverse events. The role of obesity in intensive care and its effects on mortality are variable, and it is important to recognize that obese patients are more susceptible to acute lung injury, respiratory distress, and cardiac and cerebrovascular pathologies. Nutritional evaluation is of vital importance in obese patients to reduce the risk of complications. It is recommended that it is to administer 70% of the energy requirements to patients with obesity in ICU. The objective of nutrition is to achieve progressively in the first 48–72 h to avoid overnutrition, and they propose to use between 11 and 14 kcal/kg of real body weight/day for a BMI of 30 to 50 kg/m^2, 22–25 kcal/kg ideal weight/day for a BMI > 50 kg/m^2.

Keywords: nutritional status, nutritional sciences, nutritional therapy, nutritional support, obesity

1. Introduction

Obesity, a preventable disease that has tripled in most regions of the world, begins when BMI is >30 kg/m^2, the result of a mixture of genetic, environmental, psychological, and lifestyle factors associated with adverse events, cerebrovascular, coronary artery events, angina pectoris and the need for hospitalization. The role of obesity in intensive care and its effects on mortality are variable [1–4].

Obesity has become a public health problem (**Figure 1**); in the adult population, costs increase with hospitalizations associated with obesity, and the dose of

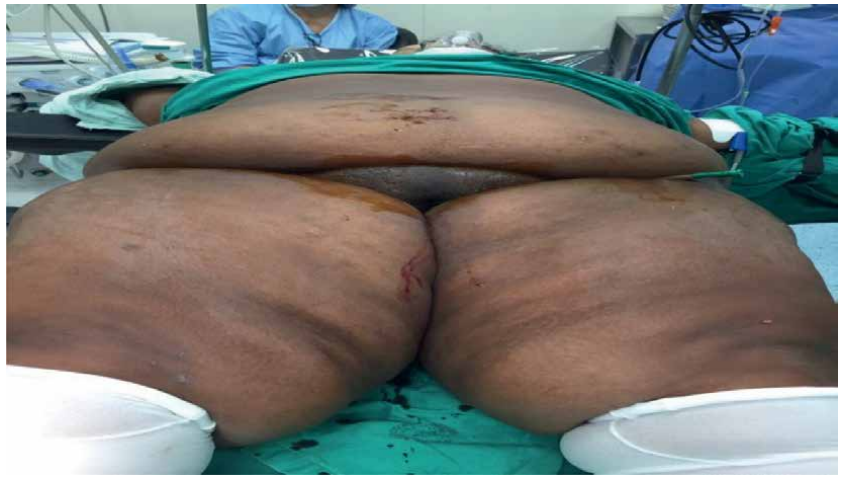

Figure 1.
Morbidly obese patients in the intensive care unit, obesity represents a challenge for ICU staff.

medication administration differs in its distribution according to body mass index and inflammatory response [5, 6].

Obesity increases the risk of respiratory, cardiovascular, and endocrinological diseases such as diabetes or hypothyroidism and pancreatic diseases. One of its main etiological causes is genetics since there are several genes that encode the proteins of the hypothalamic leptin/melanocortin pathway, producing obesity [7–9].

Nutrigenomics is the science that studies the genetic consequences of nutrition, and it is important to recognize that obese patients have an increased susceptibility to acute lung injury, respiratory distress secondary to the regulation of cell signaling pathways, and genetic and molecular mechanisms that worsen acute lung injury [10].

The mortality rate (see **Table 1**) of obesity ranges from 28.2% to 31.5% in ICUs with a prevalence of 20%; however, it is increasing in adult and pediatric patients, demonstrating harmful effects on health, mainly in patients who have a BMI > 50 kg/m^2 and who represent the most severe cases. Becoming a challenge for health personnel in intensive care units due to the difficulty of their management and care in the administration of medications, hospital transfer, resuscitation, or diagnostic imaging. A study that assessed both BMI and waist size ratio observed that it is necessary to take into consideration other anthropometric measures to assess mortality since the abundant lean mass of some patients influences BMI through muscle training. This can give a high BMI without being obese; once adjusted with central obesity, critically obese patients have more mortality and complications in the ICU [11–13].

For example, obese patients undergoing cardiopulmonary resuscitation have higher in-hospital mortality and poor neurological prognosis compared to patients without obesity [14]. Obesity is also associated with an increased risk of sepsis, high blood pressure, and difficulty in airway intubation; morphological changes in the structures of the neck, thorax, and abdomen present greater complications in mechanical ventilation due to their altered anatomy with higher mortality [15, 16].

Pathophysiological, the obese patient is subjected to nutritional changes, neuroendocrine hormonal alterations, inflammatory processes, activation of immune mechanisms, and hypoventilation. The benefits of enteral and parenteral nutritional therapy in severely obese patients are a topic of great importance [17, 18].

Author/Intervention	Population	Results	Mortality
Charles et al. Low-energy diets do not improve outcomes in critically ill patients with obesity.	Obese and critically ill adult surgical patients	The administration of 25–30 kcal/kg of a normocaloric diet was compared with 12.5–15 kcal/kg hypocaloric, and there was a trend toward more infections in the group with a normocaloric diet: 87.1% compared to 63.6% in the group that received a hypocaloric diet.	10% in the obese group and 7.6% in the non-obese group
Tweel et al./ Comparison of high-dose and usual protein in severely obese patients	Severely obese patients in ICU	High doses of protein (≥ 2.2 g/kg/day) versus usual dose (≤ 1.2 g/kg/day) with no significant differences.	Mortality: 31.5% at high intake and 28.2% at regular protein intake
Ichimaru et al./ Energy intake in the first week in the ICU	Japanese patients with overweight and serious diseases, Group A with <50% of the requirement, and Group B with > = 50%.	Ventilator-free days were significantly higher in group A than in group B (20.0 [15.5–24.5] vs. 17.0 [2.0–21.0] days; p = 0.042).	Not rated
DeLapp et al./ Obesity, long-term outcomes in hospitalization for COPD exacerbation	Patients hospitalized for acute exacerbation of COPD with BMI >30	Patients with obesity had a significant reduction in the odds of dying at one year (p = 0.004) at six months (p = 0.031).	Mortality of patients with and without obesity (7 and 18% at six months and 8–28% after one year)

Prepared by: Javier Aquiles Hidalgo Acosta. **Table 1** *compares randomized clinical trials on the number of kilocalories, protein doses, energy requirements, and mortality of critically ill obese patients [22–25].*

Table 1.
Population, Outcomes, and Mortality of Obesity in ICUs.

Mainly, it must be taken into consideration due to thoracic alterations and reduced lung capacity, and it is necessary to secure the airway, keep it permeable, and have a team trained in difficult airways and an expert surgeon in emergency tracheostomy [19].

The position of the stretcher in obese patients can influence their recovery during their stay in intensive care, in a study that compared this, the group in the inverted Trendelenburg position had a marked improvement compared to the group in the reclined position [20].

In terms of oral and dental health, it is important to clean the oral area with 0.2% chlorhexidine to prevent oral infections from proliferating and generating healthcare-associated infections [21].

2. Methodology

A review of articles published in the last 5 years in databases such as Wiley, PubMed, SciELO, Latindex, and ScienceDirect on the topic of nutritional research in obese patients in ICU and its current management was carried out. Through a research question: What is the ideal nutrition for the critically obese patient? How to nourish obese patient in the intensive care unit? What is the importance of micronutrients in critically obese people? The search words were critically obese, obese in ICU, and nutrition of obese in ICU; observational studies, controlled trials, systematic

reviews, clinical guidelines, and meta-analyses on the research topic were obtained, for the selection of the most important articles with positive and negative results of nutrition in critical care were assessed, As final outcomes, we searched for studies on types of nutrition and morbidity and mortality in intensive care units.

3. Morbidity, mortality, and nutrition of critically obese patients

Obesity increases morbidity as observed in **Figure 1** a morbidly obese patient admitted to the ICU due to complications of her pregnancy, for which emergency cesarean section was performed, which shows that obesity can complicate hospitalization in the intensive care unit. In **Table 1**, studies in ICUs aimed at nutritional interventions to administer the number of kilocalories necessary to prevent malnutrition in critically obese patients; initially, nutrition must be constituted by the total amount of calculated kilocalories, number of proteins, and carbohydrates necessary to provide energy to the cell. It is important to mention that the obesity paradox was fulfilled in long-term hospitalized patients with COPD exacerbation, these had the lowest mortality between 7% and 8%, in obese surgical patients the mortality was 10%, and in the most severe cases of obesity it represented 28.2% to 31.5%.

4. Management of critically obese patients

The NUTRIC scale is the first nutritional risk assessment tool developed and validated specifically for ICU patients; a value >5 indicates a high risk of malnutrition in critically ill patients [26].

Actual body weight is measured during hospitalization, ideal body weight is weight related to height, adjusted body weight is applicable in overweight patients (actual body weight − ideal body weight) × 0.33 + ideal body weight for patients with a BMI of up to 30 kg/m^2 for obese patients ideal body weight based on the patient's height is used [27].

The normocaloric diet refers to the administration of energy around a defined goal of 70–100% of the nutrition goal of the critically obese, the hypocaloric diet is defined with an energy administration below 70% of the defined goal, trophic feeding is a minimum administration of nutrition due to the beneficial effects of enteral nutrition on the intestinal epithelium, enzyme secretion, immunity and prevent bacterial translocation. Supercharging is the administration of energy 110% above the defined target. The low-protein diet is low in protein and consists of a protein administration of less than 0.5 g/kg/day [28].

5. Obesity and nutrition in critically ill patients

Preoperative evaluation of obese patients may decrease the risk of complications. ESPEN recommends that it is necessary to administer 65 and 70% of the energy requirements to patients with obesity in the ICU; the goal should be achieved progressively and not before the first 48–72 h to avoid overnutrition; ASPEN proposes to use between 11 and 14 kcal/kg of real body weight/day for a BMI of 30 to 50 kg/m^2, 22–25 kcal/kg ideal body weight/day (for BMI > 50 kg/m^2) [29].

ESPEN recommends calculating kilocalories at 20–25 kcal/kg adjusted body weight/day, and a usual protein dose for obese people is 1.2 g/kg ideal weight/day [30].

6. Nutritional requirements

The corrected or adjusted weight formula helps to estimate the nutritional needs of critically ill patients with obesity, for more accuracy, it is advisable to perform the calculation by adjusting the patient's weight [31–34]. The nutrition to be passed through the enteral or parenteral route through a central venous catheter is calculated; everything depends on the integrity of the digestive tract or contraindication to initiate enteral nutrition; critically obese patients with lack of integrity of the digestive system due to previous surgeries have a higher risk of malnutrition due to lack of micronutrients, macronutrients, or electrolytes [35, 36].

Adjusted body weight = (actual body weight − ideal body weight) × 0.33 + ideal body weight; this value is multiplied by the kilocalories to be administered:

- Obese BMI of 30–50 kg/m^2, administer 11–14 kcal/kg by actual body weight per day.

- Superobese BMI greater than 50 kg/m^2, 22–25 kcal/kg by adjusted body weight per day.

- Overweight BMI up to 30 kg/m^2, 25–30 kcal/kg is used for adjusted body weight.

The necessary daily dose of protein is 2 g/kg for adjusted weight, 20–30% of the total kilocalories calculated have to be proteins, each g of protein administered provides 4 kcal which constitutes the calories of protein origin.

Carbohydrates are non-protein calories and account for 30–40% of total calories.

Start with 70% of what was initially calculated, increasing every 8 hours if it tolerates well until reaching 100% of the total requirements in 24–48 hours.

Indirect calorimetry is the test that serves to measure the energy balance, and it is the most reliable method to measure energy expenditure. This test allows one to know individually the energy expenditure of each patient, and it can also be performed in patients on mechanical ventilation by connecting the calorimetry sensors to the closed circuit of the mechanical ventilator [37].

The micronutrients used in ICU include trace elements such as selenium, zinc, copper, manganese and vitamins C, D and B [38, 39], they are necessary for immunomodulation, inflammatory response and enzymatic reactions, this is the reason for their importance in people with obesity admitted to the intensive care unit [40], micronutrients can be obtained through enteral nutrition that provides daily needs, In cases of parenteral nutrition, it is necessary to provide micronutrients intravenously to avoid deficiency [41], the strategy of parenteral supplementation with antioxidants in severely obese patients should be carried out considering factors such as the length of hospital stay, type of nutrition received by the patient, history of alcoholism, cirrhosis, vomiting, diarrhea, fistulas, renal replacement therapy cause copper deficiency, carnitine and vitamin B6, vitamin C, selenium and zinc, the current literature is limited by the lack of more clinical trials and randomized research with solid evidence on these topics. Other complementary components to parenteral nutrition are electrolytes such as sodium, potassium, calcium, phosphorus, and magnesium which are constantly needed during ICU nutrition [42, 43].

Nutritional management in critically obese patients is highly complex, and this condition complicates treatment and follow-up in the ICU; for this reason, more research is needed on the nutritional care of critical obesity; there are still knowledge

gaps in this field to be deciphered such as immunomodulatory formulas, hypocaloric diets, mixed nutrition, parenteral supplementation with omega-3 fatty acids in the field of severe obesity in critical care need more trials randomized clinical studies and studies on the types of nutrition in obese patients [44].

7. Conclusions

The nutrition of the critically obese deserves timely attention to establish an adequate normocaloric, normoprotein diet, due to the global impact it has on almost all organs and systems of the human body; currently, there are methods such as enteral and parenteral nutrition that complement treatment in the ICU, adequate nutrition according to the kilos of weight of each person.

Obese patients represent a high risk of overeating, for this reason, it is necessary to take into consideration the ideal weight and the real weight; the requirements are adjusted to achieve the initial goal until 100% of the calories calculated progressively are achieved.

Critically obese patients have high morbidity and mortality in intensive care units, which makes their management difficult. Nutrition in obese patients is a current issue due to the special and growing needs that this disease requires for its management, and more studies are needed on all types of nutrition. The ideal nutrition in critically ill patients with obesity needs to be the subject of future lines of research due to its vital importance.

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Conflict of interest

The authors declare no conflict of interest.

Notes/thanks/other declarations

Thank you.

Acronyms and abbreviations

BMI	body mass index
ICU	intensive care unit
ASPEN	American society of parenteral and enteral nutrition
ESPEN	European society of clinical nutrition and metabolism
NUTRIC	nutrition risk in the critically ill

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References

[1] World Health Organization (WHO). Obesity and Overweight. Geneva: Press Centre; 2021. Available from: https://www.who.int/es/news-room/fact-sheets/detail/obesity-and-overweight [Accessed: January 13, 2024]

[2] Nseir S, Le Gouge A, Pouly O, Lascarrou JB, Lacherade JC, Mira JP, et al. Relationship between obesity and ventilator-associated pneumonia: A post hoc analysis of the trial NUTRIREA2. Chest. 2021;**159**(6):2309-2317. DOI: 10.1016/j.chest.2021.01.081

[3] Al-Dorzi HM, Stapleton RD, Arabi YM. Nutrition priorities in obese critically ill patients. Current Opinion on Clinical Nutrition and Metabolic Care. 1 Mar 2022;**25**(2):99-109. DOI: 10.1097/MCO.0000000000000803

[4] Wiebe N, Lloyd A, Crumley ET, Tonelli M. Associations between body mass index and all-cause mortality: A systematic review and meta-analysis. Obesity Reviews. 2023;**24**(10):E13588. DOI: 10.1111/obr.1358820

[5] Destri K, Henriques AR, Mendonça N, Alves J, Barcelos A, Dias SS, et al. Hospitalization costs in Portugal among people with obesity: Results from a national population-based cohort from 2011 to 2021. Public Health Frontiers. 2024;**12**:1380690. DOI: 10.3389/fpubh.2024.1380690

[6] Zhang T, Krekels EHJ, Smit C, van Dongen EPA, Brüggemann RJM, Knibbe CAJ. How to dose vancomycin in overweight and obese patients with variable renal dysfunction in the new era of targeted dosing at AUC 400-600 mg·h/L. Clinical Pharmacokinetics. 2024;**63**(1):79-91. DOI: 10.1007/s40262-023-01324-5

[7] Moore Heslin A, McNulty B. Adolescent nutrition and health: Characteristics, risk factors and opportunities of an overlooked life stage. The Proceedings of the Nutrition Society. 2023;**82**(2):142-156. DOI: 10.1017/S0029665123002689

[8] Jin Z, Wang Z, Wang J. Early enteral nutrition prevents deterioration of acute pancreatitis in obese patients. Journal of Clinical Gastroenterology. 2020;**54**(2):184-191. DOI: 10.1097/MCG.0000000000001117

[9] Gato-Moreno M, Martos-Lirio MF, Leiva-Gea I, Bernal-López MR, Vegas-Toro F, Fernández-Tenreiro MC, et al. Early nutritional education in the prevention of childhood obesity. International Journal of Environmental Research and Public Health. 2021;**18**(12):6569. DOI: 10.3390/ijerph18126569

[10] Harshman SG, Castro I, Perkins M, Luo M, Barrett Mueller K, Cena H, et al. Pediatric weight management interventions improve the prevalence of overeating behaviors. International Journal of Obesity. 2022;**46**(3):630-636. DOI: 10.1038/s41366-021-00989-x

[11] Goulding K, Marchetti R, Perera R, Johnson R, Bailey M, Secombe P. Does the use of BariBoard™ improve the adequacy of chest compressions in morbid obesity? A pilot study using a simulation model. Australian Critical Care. 2022;**35**(6):688-695. DOI: 10.1016/j.aucc.2021.09.009

[12] Li S, Fu Z, y Zhang, W. Association of Anthropometric Measures with all-cause and cause-specific mortality in U.S. adults: A review of the obesity paradox. BMC Public Health. 2024;**24**:929. DOI: 10.1186/s12889-024-18418-9

[13] Prakash J, Verma S, Shrivastava P, Saran K, Kumari A, Raj K, et al. Modified NUTRIC score as a predictor of all-cause mortality in critically ill patients: A systematic review and meta-analysis. Indian Journal of Critical Care Medicine. 2024;**28**(5):495-503. DOI: 10.5005/jp-journals-10071-24706

[14] Kojima M, Mochida Y, Shoko T, Inoue A, Hifumi T, Sakamoto T, et al. Association between body mass index and clinical outcomes in patients with out-of-hospital cardiac arrest undergoing extracorporeal cardiopulmonary resuscitation: A multicenter observational study. Resuscitation Plus. 2023;**16**:100497. DOI: 10.1016/j.resplu.2023.100497

[15] Falls C, Melander S. Obesity in the intensive care setting. The Nursing Clinics of North America. 2021;**56**(4):573-581. DOI: 10.1016/j.cnur.2021.08.002

[16] Li C, Islam N, Gutiérrez JP, Gutiérrez-Barreto SE, Castañeda Prado A, Moolenaar RL, et al. Associations of diabetes, hypertension, and obesity with COVID-19 mortality: A systematic review and meta-analysis. BMJ Global Health. 2023;**8**(12):E012581. DOI: 10.1136/bmjgh-2023-012581

[17] Zhang SJ, Qin XZ, Zhou J, He BF, Shrestha S, Zhang J, et al. Adipocyte dysfunction promotes lung inflammation and aberrant repair: A potential target of COPD. Frontier Endocrinology (Lausanne). 2023;**14**:1204744. DOI: 10.3389/fendo.2023.1204744

[18] Patout M, Gagnadoux F, Rabec C, Trzepizur W, Georges M, Perrin C, et al. AVAPS-AE versus ST mode: A randomized controlled trial in patients with obesity hypoventilation syndrome. Respirology. 2020;**25**(10):1073-1081. DOI: 10.1111/resp.13784

[19] Beloncle FM, Richard JC, Merdji H, Desprez C, Pavlovsky B, Yvin E, et al. Advanced respiratory mechanics assessment in obese and non-obese mechanically ventilated patients with or without acute respiratory distress syndrome. Critical Care. 2023;**27**(1):343. DOI: 10.1186/s13054-023-04623-2

[20] Hassan EA, Baraka AAE. The effect of reverse Trendelenburg position versus semi-recumbent position on respiratory parameters of critically ill obese patients: A randomized controlled trial. Journal of Clinical Nursing. 2021;**30**(7-8):995-1002. DOI: 10.1111/jocn.15645

[21] Pushparaja S, Akshatha S. Overweight and obesity in children: Implications for oral health. Gaceta Médica de México. 2020;**156**(5):485-485. Available from: http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0016-38132020000500485&lng=es [Accessed: September 8, 2024. DOI: 10.24875/gmm.20000500

[22] Charles EJ, Kane WJ, Willcutts KF, O'Donnell KB, Petroze RT, Sawyer RG. Low-energy feeding does not improve outcomes in critically ill patients with premorbid obesity: A post hoc analysis of a randomized controlled trial. Nutrition Research. 2020;**74**:71-77. DOI: 10.1016/j.nutres.2019.11.011

[23] Tweel LE, Compher C, Bear DE, Gutierrez-Castrellon P, Leaver SK, MacEachern K, et al. A comparison of high-dose and usual protein intake in critically ill patients with obesity: A post hoc analysis of an international, pragmatic, single-blind, randomized clinical trial. Critical Care Medicine. 2024;**52**(4):586-595. DOI: 10.1097/CCM.0000000000006117

[24] Ichimaru S, Sono M, Seo R, Ariyoshi K, Amagai T. Energy intake in

the first week in an emergency intensive care unit may not influence clinical outcomes in overweight, critically ill Japanese patients. Asia Pacific Journal of Clinical Nutrition. 2017;**26**(6):1016-1020. DOI: 10.6133/apjcn.022017.01

[25] DeLapp DA, Glick C, Furmanek S, Ramírez JA, Cavallazzi R. People with obesity have better long-term outcomes after hospitalization for COPD exacerbation. COPD. 2020;**17**(4):373-377. DOI: 10.1080/15412555.2020.1781805

[26] Reis AMD, Fructhenicht AVG, Moreira LF. NUTRIC score use around the world: A systematic review. Revista Brasileira de Terapia Intensiva. 2019;**31**(3):379-385. DOI: 10.5935/0103-507X.20190061

[27] Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, Casaer MP, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clinical Nutrition. 2019;**38**(1):48-79. DOI: 10.1016/j.clnu.2018.08.037

[28] Singer P, Blaser AR, Berger MM, Calder PC, Casaer M, Hiesmayr M, et al. ESPEN practical and partially revised guideline: Clinical nutrition in the intensive care unit. Clinical Nutrition. 2023;**42**(9):1671-1689. DOI: 10.1016/j.clnu.2023.07.011

[29] Schetz M, De Jong A, Deane AM, Druml W, Hemelaar P, Pelosi P, et al. Obesity in the critically ill: a narrative review. Intensive Care Medicine. Jun 2019;**45**(6):757-769. DOI: 10.1007/s00134-019-05594-1

[30] Lambell KJ, Miller EG, Tatucu-Babet OA, Peake S, Ridley EJ. Nutrition management of obese critically ill adults: A survey of critical care dietitians in Australia and New Zealand. Australian Critical Care. 2021;**34**(1):3-8. DOI: 10.1016/j.aucc.2020.06.005

[31] Arroyo Sánchez AS. Indirect calorimetry in critical care: a narrative review. Journal of Clinical Nutrition and Metabolism. 2020;**3**(2):45-56. DOI: 10.35454/rncm.v3n2.88

[32] Bianchi A, Pagan-Pomar A. Need of a specialised care unit for patients with morbid obesity. Anales del Sistema Sanitario de Navarra. 2023;**46**(1):e1037. Spanish. DOI: 10.23938/ASSN.1037

[33] Pérsico RS, Souza GC, Franzosi OS, Rovati BAR, Santos ZEA. Nitrogen balance in obese patients mechanically ventilated. Revista de Nutrição. 2021;**34**:E190263. DOI: 10.1590/1678-9865202134e190263

[34] Thawkar VN, Taksande K. Navigating nutritional strategies: Permissive undernourishment in critically ill patients. Cureus. 2024;**16**(4):e58083. DOI: 10.7759/cureus.58083

[35] Correia MITD, Rosenfeld RS. Nutritional management during critical illness in those with previous obesity surgery. Current Opinion in Clinical Nutrition and Metabolic Care. 2024;**27**(2):192-199. DOI: 10.1097/MCO.0000000000001014

[36] Munoz N, Litchford M, Cox J, Nelson JL, Nie AM, Delmore B. Malnutrition and pressure injury risk in vulnerable populations: Application of the 2019 international clinical practice guideline. Advances in Skin & Wound Care. 2022;**35**(3):156-165. DOI: 10.1097/01.ASW.0000816332.60024.05

[37] Bendavid I, Lobo DN, Barazzoni R, Cederholm T, Coëffier M, de van der Schueren M, et al. The centenary of the Harris-Benedict equations: How to assess energy requirements best? Recommendations from the ESPEN

expert group. Clinical Nutrition. 2021;**40**(3):690-701. DOI: 10.1016/j.clnu.2020.11.012

[38] Gudivada KK, Kumar A, Shariff M, Sampath S, Varma MM, Sivakoti S, et al. Antioxidant micronutrient supplementation in critically ill adults: A systematic review with meta-analysis and trial sequential analysis. Clinical Nutrition. 2021;**40**(3):740-750. DOI: 10.1016/j.clnu.2020.06.033

[39] Gundogan K, Yucesoy FS, Ozer NT, Temel S, Sahin S, Sahin GG, et al. Serum micronutrient levels in critically ill patients receiving continuous renal replacement therapy: A prospective, observational study. JPEN Journal of Parenteral and Enteral Nutrition. 2022;**46**(5):1141-1148. DOI: 10.1002/jpen.2378

[40] Rousseau AF, Martindale R. Nutritional and metabolic modulation of inflammation in critically ill patients: A narrative review of rationale, evidence and grey areas. Annals of Intensive Care. 2024;**14**(1):121. DOI: 10.1186/s13613-024-01350-x

[41] Chudow M, Adams B. ABC's of vitamin supplementation in critical illness. Journal of Pharmacy Practice. 2021;**34**(6):934-942. DOI: 10.1177/0897190020958234

[42] Gudivada KK, Kumar A, Sriram K, Baby J, Shariff M, Sampath S, et al. Antioxidant micronutrient supplements for adult critically ill patients: A Bayesian multiple treatment comparisons meta-analysis. Clinical Nutrition ESPEN. 2022;**47**:78-88. DOI: 10.1016/j.clnesp.2021.12.015

[43] Dresen E, Pimiento JM, Patel JJ, Heyland DK, Rice TW, Stoppe C. Overview of oxidative stress and the role of micronutrients in critical illness. JPEN Journal of Parenteral and Enteral Nutrition. 2023;**47**(Suppl. 1):S38-S49. DOI: 10.1002/jpen.2421

[44] Ethel L-M, García-Montalvo, Antonio I, Contreras-Oliveros, de los Ángeles M, Macías-Moreno M. Parenteral supplementation with EPA/DHA omega-3 fatty acids improves the prognosis of recovery in critically ill patients. Nourish Hospital. 2023;**40**(1):3-12. Available from: http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0212-16112023000100002&lng=es [Accessed: September 25, 2024]. DOI: 10.20960/nh.04227

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Nutrition During Intensive Care is a comprehensive guide for healthcare professionals dedicated to improving patient outcomes in ICU settings. Edited by Mahsa Jalili, an assistant professor in clinical nutrition with over a decade of experience in nutrition, this book investigates the practical challenges of managing the nutritional needs of critically ill patients. Drawing on extensive research and clinical practice, the book addresses key topics such as nutritional assessment, enteral and parenteral nutrition, and the unique challenges faced by obese patients in the ICU. It also explores the critical role of thiamin and the impact of nutrient–drug interactions. This collection of recent chapters provides valuable insights and evidence-based recommendations to enhance patient care, making it an essential resource for clinicians, nurses, and anyone involved in ICU nutrition therapy.

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