

Nutrition and Health

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Editors

Nutrition Support for the Critically Ill

 Humana Press

NUTRITION AND HEALTH

Adrienne Bendich, PhD, FASN, FACN, Series Editor

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Dedications

*To our patients, our students and trainees,
and our colleagues. And to our wives, Kesiah E. Scully
and Gail E. Van Way, without whose love, support,
and encouragement this work, and all we do,
would not be possible.*

Foreword

Nutritional support in the critically ill patient is like mother's milk, right? Indeed, there was a time, long ago and on a planet far away, when we felt we knew all the answers to feeding the critically ill. At the end of the 1970s, when I was undertaking my Fellowship in Critical Care Medicine, it was assumed that total parenteral nutrition (TPN) would ultimately take care of our sick patients' needs. To underscore the naivety of this concept, soon after my graduation as a neophyte intensivist at a major university medical center, I was appointed Chair of the Hospital TPN Committee. A classic case of the blind leading the blind!

Today, the world of nutritional support of the critically ill patient is not only far more complex but also more discouraging, because we now realize how little we know. As acute care physicians and surgeons, we continually search for evidence-based justification of our physiologically based theories. In the field of nutrition, however, we are likely to be overwhelmed by an increasing array of large randomized control trials (RCTs) that are often mutually contradictory, do not provide answers, and simply raise more questions. Moreover, the practitioner is likely to be completely overwhelmed by an extraordinary jungle of mnemonics that at last count included TICACOS, EDEN, OMEGA, REGANE, NUTRIREA 1, EPaNIC, SPN, SIGNET, REDOXS, among others.¹ And at the end of an extensive review of all the aforementioned RCTs in the *New England Journal of Medicine*, Casear and van den Bergh conclude, "These new insights limit the number of nutritional interventions that can be confidently recommended for daily critical care practice" [1].

Many are the questions that remain to be definitively answered regarding nutritional intervention in the critically ill. Should we attempt to assess nutritional status in preoperative patients undergoing major surgery (an opportunity that is obviously lacking in patients admitted to medical intensive care unit or after acute trauma)? Should we attempt to provide full feeding within the first 24 h of acute illness, trauma, or surgery? If yes, should we supplement enteral with parenteral nutrition? If no, is it

¹ **A Neophyte's Guide to Mnemonics in Nutritional RCTs:** TICACOS, The Tight Caloric Control Study; EDEN, Trophic vs. Full-Energy Enteral Nutrition in Mechanically Ventilated Patients with Acute Lung Injury; OMEGA, The Effect of Highly Purified Omega-3 Fatty Acids on Top of Modern Guideline-Adjusted Therapy after Myocardial Infarction; REGANE, The Gastric Residual Volume During Enteral Nutrition in ICU Patients; NUTRIREA 1, The Effect of Not Monitoring Residual Gastric Volume on the Risk of Ventilator-Associated Pneumonia In Adults Receiving Mechanical Ventilation and Early Enteral Feeding; EPaNIC, The Impact of Early Parenteral Nutrition Complementing Enteral Nutrition In Adult Critically Ill Patients; SPN, The Impact of Supplemental Parenteral Nutrition on Infection Rate, Duration of Mechanical Ventilation, and Rehabilitation in ICU Patients; EPN, Early Parenteral Nutrition; SIGNET, Scottish Intensive Care Glutamine or Selenium Evaluative Trial; REDOXS, Reducing Deaths Due to Oxidative Stress.

okay to allow hypocaloric enteral feedings for the first 5 days of acute illness or injury? Should we provide prokinetic agents or postpyloric feeding to avoid aspiration? Should we perform daily indirect calorimetry to assess caloric need during different phases of acute illness? How do we assess when the patient may be ready to transition from hypocaloric to full supplementation to reverse their accumulated nutritional deficit? Are there “magic bullets” that will enhance the success of nutritional support, such as glutamine, arginine, anti-inflammatory fatty acids, micronutrients, trace elements, fat-soluble vitamins or antioxidants such as selenium?

In *Nutrition Support for the Critically Ill*, David Seres and Charles Van Way and their colleagues provide a state-of-the-art resource to address the physiology, pharmacology, and evidence basis underlying these questions. This all-encompassing text addresses every conceivable aspect of nutritional support for the critically ill patient. Cogent chapters address the pathogenesis, impact, and assessment of malnutrition in the acutely ill patient; the vital role of gut endothelium and the microbiome in the immunologic response to stress and trauma; and the timing, indications, and access for enteral and/or parenteral nutrition in the critically ill. There are chapters that address nutritional support in specific situations, such as the patient admitted to a surgical intensive care unit following major trauma or surgery; the patient with severe sepsis; the patient who has developed single or multiple organ failure; or the patient with obesity. Even the ethical stone is turned, in a thoughtful consideration of whether nutritional support should be discontinued when aggressive life-prolonging interventions are futile. Practical considerations are not ignored either. There is emphasis on safe practice in enteral and parenteral nutrition; the economic impact of nutritional support; and the importance of a multidisciplinary approach to enhance patient management and outcome.

In a perfectly timed denouement, Drs. Seres and Van Way posit the many questions that remain to be fully answered by future research. Not surprisingly, these are questions that we have been asking for many years. Are there reliable markers of malnutrition and its impact on the systemic response to acute injury and sepsis? What are the important biologic interactions between the patient’s nutritional status and their immunologic response to acute illness or injury? How will we settle the great areas of controversy that remain with regard to the timing and nature of nutritional support in the acute phase of illness, especially in the face of accelerated metabolism? When does the benefit of parenteral nutrition outweigh its potential computations?

Today, in-depth training in nutritional support appears to have been confined to a tiny cul de sac in the critical care curriculum of our students, residents, and fellows. We are focused on all the exciting aspects of acute care, such as invasive monitoring and inotropic agents, the latest cure for acute respiratory distress syndrome, or increasingly miniaturized mechanical circulatory support systems. Unfortunately, this is achieved to the detriment of our understanding of the physiology, pharmacology, and evidence basis for nutritional support. As long as a feeding tube is in place and enteral feeds are started, we’re okay, right? If not, we’ll get a nutritional consult—at our institution, Dr. Seres, of course!

I am convinced that this remarkable textbook will go a long way to restore the rightful place of nutritional support as an integral component of our daily management, right up there with our short-term focus on hemodynamics, antibacterial therapy, and organ system support. *Nutrition Support for the Critically Ill* re-emphasizes the inestimable role that appropriate nutrition plays in long-term outcome in the critically ill. It enhances our knowledge and understanding of the current concepts in this essential aspect of intensive care. As such, it should be required reading for every intensivist. There should be no excuse that “there’s no way that I can digest such a big textbook” (so to speak). *Nutrition Support for the Critically Ill* has a modular approach that allows the reader to focus on individual

aspects of the theoretic, empiric, evidence-based, and practical considerations that should guide our approach today. As such, Drs. Seres and van Way and their collaborators should be lauded on their timely and much-needed contribution to the nutritional support—and overall care—of our critically ill patients. And I am honored to have been asked to be their flag-bearer!

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Preface

Nutrition is complex by its nature. Daily, we ingest hundreds of substances, comprising literally thousands of chemical entities. And yet, our bodies—plus our gut microflora, as we know now—sort these out and create homeostasis. But with all of our science and our history, we still have only a hazy idea of which nutrients are beneficial, which harmful, and how much of either should be in our diet. Worse, we change our collective minds from year to year. And that is just in normal people. Illness makes nutrition even more complex.

Patients with illnesses often use nutrients differently, or respond differently to particular nutrients. This is especially true of critically ill patients. In these most seriously ill patients, the homeostasis of so many metabolic systems goes into varying degrees of disarray. Too often, the gastrointestinal tract itself is dysfunctional. The so-called nutritional measurements such as calorie expenditure, protein utilization, and serum micronutrient and protein levels often fail to instruct us well on how we should approach nourishing our patients. The manifestations of malnourishment and the dysmetabolism of disease may be indistinguishable. It should be no surprise that the nutritional research that drives our recommendations for addressing the needs of this extraordinarily diverse patient population falls far short. All too often, we have little certainty concerning when, where, what, how much, and for how long we should feed our patients.

This book is based on evidence-based practice (EBP). But... there is significant misunderstanding about just what EBP is. When most residents or fellows are asked to describe the quality or quantity of evidence required for evidence-based practice, invariably the answer is that data from prospective, randomized studies is required. But EBP, in fact, requires no evidence whatsoever. The proper definition of EBP is practice based on *guidelines* in which the quality of the evidence has been graded. The lowest level of quality in any guideline is that which is driven solely by expert opinion, without data. But this may be all we have to support our approach to patients. As with any common terminology, meaning shifts, or is lost, as it is taken for granted.

But a sad truth about nutrition is that evidence is too often anecdotal, inadequate, or just not there. In this text, we have set out to provide the practitioner with the scientific underpinnings of these complex issues. We have tried to make the best of the evidence that we have. We have maintained as much transparency as possible when facts are weak or not present. Which is all too frequently true. We have tried to avoid the usual pitfall of opinion presented as fact. Our hope is that this approach will better prepare practitioners in the intensive care unit to evaluate not only their patients but also the advice they receive from guidelines and other professionals. Most of all, we hope to promote flexibility. No dogma lasts forever. Time-honored practices may become obsolete, or proven ineffective, or even found to be harmful as better evidence emerges and as the context of care surrounding these practices changes.

There are many textbooks and guides that will give specific guidelines for practice. We have tried to avoid this as a primary goal and suggest the reader become familiar with sources for evidence-based guidelines that are kept current. In this day and age of rapid access and constant updating, a textbook such as this is not an appropriate source for how to practice. Rather, it should be a guideline to how to *think* about the problems of nourishing our patients.

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Series Editor Page

The great success of the “Nutrition and Health” book series is the result of the consistent overriding mission of providing health professionals with texts that are essential because each includes (1) a synthesis of the state of the science, (2) timely, in-depth reviews by the leading researchers and clinicians in their respective fields, (3) extensive, up-to-date fully annotated reference lists, (4) a detailed index, (5) relevant tables and figures, (6) identification of paradigm shifts and the consequences, (7) virtually no overlap of information between chapters, but targeted, interchapter referrals, (8) suggestions of areas for future research, and (9) balanced, data-driven answers to patient as well as health professionals questions which are based upon the totality of evidence rather than the findings of any single study.

The series volumes are not the outcome of a symposium. Rather, each editor has the potential to examine a chosen area with a broad perspective, both in subject matter and in the choice of chapter authors. The international perspective, especially with regard to public health initiatives, is emphasized where appropriate. The editors, whose trainings are both research and practice oriented, have the opportunity to develop a primary objective for their book; define the scope and focus, and then invite the leading authorities from around the world to be part of their initiative. The authors are encouraged to provide an overview of the field, discuss their own research, and relate the research findings to potential human health consequences. Because each book is developed *de novo*, the chapters are coordinated so that the resulting volume imparts greater knowledge than the sum of the information contained in the individual chapters.

Nutrition Support for the Critically Ill edited by David S. Seres, MD and Charles W. Van Way, III, MD is a welcome addition to the “Nutrition and Health” book series. The editors are experts in the care of seriously ill patients and have significant expertise in the development of nutritional strategies to aid in the stabilization of the energy and essential nutrient requirements of the acutely ill patient. They have invited the leaders in the field to develop the 16 relevant, practice-oriented chapters in this unique and clinically valuable volume. David S. Seres, MD, ScM, PNS, is Director of Medical Nutrition and Associate Professor of Medicine in the Institute of Human Nutrition, Columbia University Medical Center, New York, NY. Dr. Seres has 25 years’ experience as a nutrition support specialist. He directs the nutrition support service, the medical school nutrition curriculum, and one of the few clinical nutrition fellowships for physicians in the USA. He was recipient of the 2014 Excellence in Nutrition Education Award from the American Society for Nutrition. Dr. Seres is also a clinical ethicist and a Columbia University/OpEd Project Public Voices Fellow. Dr. Seres is a member of the Medical Advisory Board for Consumer Reports. He was Chair of Physician Certification for the National Board of Nutrition Support Certification, and Chair of the Medical Practice Section for the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). Dr. Seres’ research includes

improving nutrition content in medical school curricula, the impact of feeding tube choice on patient outcomes and the indications for placing feeding tubes in patients placed in nursing homes, the risk of blood-stream infections in patients receiving parenteral nutrition, and metabolic derangements in acute illness. Charles W. Van Way, III, MD, FACS, F.C.C.M., F.C.C.P., FASPEN, is Director of Metabolic Support at Truman Medical Center, and Emeritus Professor of Surgery at the University of Missouri, Kansas City. He has nearly 50 years of clinical experience in nutrition support, dating back to his surgical residency at Vanderbilt University. Dr. Van Way is semi-retired and maintains his clinical practice in nutrition and critical care. He is the Director of the Shock Trauma Research Center of UMKC and continues research on nutrition support and on post-shock inflammation. Dr. Van Way served as the past President of the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) and as President of the A.S.P.E.N. Rhoades Research Foundation. He has been Editor in Chief of both the *Journal of Parenteral and Enteral Nutrition* and *Nutrition in Clinical Practice*. Dr. Van Way has more than 400 clinically related publications.

Nutrition Support for the Critically Ill fulfills an unmet need for health professionals including pediatric and adult medical specialists, residents and fellows, internists, pediatricians, nurses, dietitians, and general practitioners who treat patients who have often been seriously injured or at a critical juncture in disease progression. Several chapters address the specialized nutrition support that is needed to help the patient recover from critical illnesses that can affect multiple organ systems, can cause significant metabolic changes, and can adversely affect the ability to consume food orally. There are in-depth reviews of the hypermetabolic state that can result in severe catabolism of the body's reserves of protein, fat, and essential macro- and micronutrients. Malnutrition in critically ill patients is strongly associated with infection and impaired healing that is examined in the comprehensive chapter on immunity. A number of chapters provide recommendations for patients who are unable to consume food orally during critical illness and require specialized nutrition support provided as either enteral nutrition or intravenous, parenteral nutrition. Unique, relevant chapters include a critical discussion of ethical considerations of nutrition support for the critically ill patients and a separate chapter that reviews the economic impact of nutrition support. Thus, the volume contains comprehensive, relevant chapters for health professionals and advanced graduate, allied health and medical students interested in the care of the nutritional needs of the critically ill patient.

This volume provides data-driven advice concerning the balance between implementation of nutritional interventions and determining the value of such interventions for critically ill patients from infancy to adulthood. The book includes an introduction to the complexities involved in determining the cause of malnutrition in the critically ill patient and the metabolic consequences. The chapters are written by experts in their fields and include the most up-to-date scientific and clinical information. The volume provides chapters that can answer critical questions for health professionals as well as knowledgeable family members, educators, and others involved in the care of the critically ill patient.

Chapter 1, written by Dr. Seres, the volume's co-editor, provides an historic overview of the care of critically ill patients who are considered as malnourished. The numerous potential causes of malnutrition and the differences between malnutrition in the seriously ill patient with symptoms associated with inflammation compared to the malnourished individual who requires replenishment of calories/nutrients are reviewed in depth. There is also a discussion of newer definitions of malnutrition that reflect the patient's pathophysiology rather than concentrating on the presumed nutritional status. Chapter 2 reviews the importance of nutritional adequacy in the development of robust immune responses that are essential to prevent serious morbidity in the critically ill patient. The chapter, containing over 100 references and relevant tables and figures, reviews the importance of both the intestinal immune system and non-immunological aspects that prevent gut bacteria from becoming pathogenic. The chapter includes detailed descriptions of the immune cells, factors, and secretions and their mechanisms of action in the gut and systemically. There are insightful discussions of the effects of parenteral versus enteral nutrition on the intestinal lining, gut microbiome, as well as the gut immune system. The next chapter, Chap. 3, reviews the methodologies used for comprehensive patient

assessment in the intensive care unit (ICU) and the importance of multidisciplinary nutrition care to help ensure the proper route and timing for nutrition therapy that can promote a favorable patient outcome. The chapter includes an in-depth review of screening tools, including the Malnutrition Screening Tool, and the Malnutrition Universal Screening Tool for use in critical care because it includes a factor for acute illness. Both tables and figures add greatly to the understanding of the complexities involved in the rapid and accurate assessment of the ICU patient.

Chapters 4 and 5 examine the critical role of enteral nutrition (EN) for the critically ill patient. The chapters integrate clinical practice with the underlying science and summarize the evidence related to international recommendations for the timing of initiation, methods of delivery, and indications for enteral nutrition in the ICU. Chapter 4 recommends early enteral nutrition for patients who are likely to require ICU care for longer than 2 days and this should commence within the first 24 h of admission to an ICU. Early enteral nutrition has been shown to reduce mortality, reduce gut dysfunction, prevent ventilator-associated pneumonia, and shorten the duration of mechanical ventilation and ICU stay. Chapter 5 is coauthored by Donald F. Kirby, who is a co-editor of a volume entitled *Handbook of Clinical Nutrition and Stroke* which is also included in the “Nutrition and Health” book series. Chapter 5, containing over 100 references and relevant tables and figures, highlights the practice-oriented options for enteral access in critically ill patients and the complications that can be encountered. Options for enteral access that are reviewed include the blind placement of nasal and oral feeding tubes ending in the stomach or further into the small intestine; facilitated placement of nasal feeding tubes; gastrostomy or jejunostomy tubes. The latter are placed using endoscopic, radiologic, laparoscopic, or open surgical techniques. There are also discussions concerning the decision-making considerations involved in the determination of the placement of the feeding tube into the stomach or into the small intestine that is often based upon the expected length of EN, either for a short time (<4 weeks) or long term (≥ 4 weeks).

Chapters 6 and 7 provide an historic perspective of the use of parenteral nutrition (PN) for patients who have gastrointestinal deficits that do not permit the use of either oral feeding or enteral nutrition and review the methods of delivering the PN and potential complications that are seen with this intervention. The development of PN solutions and balanced nutrients and advanced delivery methods have resulted in the ability to use PN in the ICU in patients who do not get sufficient nutrients from EN or cannot tolerate EN. Chapter 6 reviews the three large randomized studies of PN in critically ill patients. The three trials that included more than 6000 patients showed that early administration of supplemental PN did not have a clinical benefit. Unexpectedly, one of the studies showed net harm by early administration of supplemental PN. The comprehensive review of the data concerning the use of PN in critically ill patients points to delay in starting PN rather than the expected benefit from early administration of PN. Chapter 7 provides a detailed description of the flow of blood through the veins of the body as PN is delivered into the venous system. The benefits and risks of peripheral versus central venous catheter placement for provision of PN are also reviewed. The importance of the peripherally inserted central catheter (PICC) for delivery of PN directly into the vena cava near the heart’s atrium is examined in detail. In addition to the types of access available, there is a comprehensive discussion of the composition of the PN and the potential for certain adverse metabolic effects with the institution of PN in the ICU patient. Additionally, patients on PN for a prolonged period are at risk for hepatic and renal failure, as well as bone disease and other adverse effects.

The next four chapters provide detailed insights into the management of specific population groups often seen in the ICU who require specialized nutritional care. Chapter 8, written by Dr. Van Way, the volume’s co-editor, concentrates on the delivery of nutrients to the surgical patient in the ICU. We learn that surgical patients need intensive care because they have had a major acute event, usually either an injury or an operation. Major surgery is associated with the same acute response as seen with any type of severe physical stress and the chapter describes in detail the endocrine events, inflammatory response, and metabolic responses that affect the nutritional needs of the patient. Specific considerations of nutritional requirements for patients based upon the causes of the acute stress, including

severe burns, multiple injuries followed by surgery, stab wounds, military injuries, and others, are reviewed. The length of the hypermetabolic state, the prior intake of food, and the potential length of stay in the ICU are considered as well prior to determination of the route of nutritional support. There are detailed discussions of the nutritional needs of patients with abdominal surgeries, head injuries, and burn victims as well as the importance of specific nutrients including glutamine and other immuno-nutrients. Chapter 9 is coauthored by Dr. Seres, the volume's co-editor, and continues with the discussion of the nutritional requirements of ICU patients with serious local infections and/or sepsis. The chapter reviews the intestinal immune system and the risk of developing infection in the starved patient, and the sequence of events that may result in sepsis in patients receiving EN or PN. There is a discussion of the studies that have tested the value of immune-nutrition and other nutritional interventions in septic patients and those with severe infections. The chapter contains over 100 relevant references that point to the differences in findings between studies that have resulted in inconsistent guidelines and recommendations for the nutritional interventions for the patient with sepsis.

Organ failure can be the reason for admission to the ICU or may be a secondary consequence while in the ICU. Organs frequently affected include the lungs, liver, and kidney and/or multiple organ failure. Chapter 10, containing over 100 targeted references, examines the literature describing the results from clinical studies on the potential for specialized EN formulations to provide better outcomes for organ failure patients. Hyperglycemia and its negative effects on the immune system and metabolic activities are reviewed as hyperglycemia is a common, serious metabolic disturbance found in both diabetic and nondiabetic critically ill patients. Chapter 11 provides insights into the care of the obese patient in the ICU setting. As the percentage of obese individuals increases in the global population, there is a parallel increase in the number of obese patients admitted to the ICU. We learn that over 25 % of patients in the ICU are obese. Unfortunately, there are limited data available on nutrition therapy for obese hospitalized patients. The chapter reviews the limited scientific evidence for the metabolic care of hospitalized patients with obesity and provides practical suggestions and techniques for delivering, managing, and monitoring nutrition therapy. Detailed, practice-oriented guidelines for determining protein needs and nitrogen balance for the obese, critically ill patient are provided. The chapter includes 100 references, four tables, two case studies, and one figure that are most helpful in evaluating the effects of obesity on the nutritional well-being of the ICU patient.

Important considerations for the patient, family members, as well as the medical team are the ethical issues of nutritional support for the ICU patient especially when end-of-life decisions are being discussed. Chapter 12 provides sensitive discussions of methodologies that can be implemented proactively to help prepare all members of the ICU team if and when decisions need to be made regarding provision of nutrients and fluids to the patient. The chapter includes a detailed review of the four basic tenets of ethical decision making: autonomy, beneficence, non-maleficence, and distributive justice. Autonomy is the primary guide and refers to the right of any adult of sound mind to determine what will be done or not done to his or her body. Healthcare decisions must be made based on what is best for the patient after an educated conversation has taken place. Beneficence, or doing good for patients, is defined as acting in the best interests of the patient. The author indicates that fluid resuscitation, endotracheal intubation, and initiation of artificial nutrition and hydration (ANH), when the benefits outweigh the burdens, are examples of beneficence in action. Similarly, forgoing ANH where the burdens/risks outweigh the benefits is also an act of beneficence, since such action, objectively, is in the patient's best interest. Non-maleficence is defined as avoiding harm. In addition, the healthcare team is obligated to refrain from providing ineffective treatments. Under distributive justice, patients should all be treated equally, allowing for the differences in their clinical requirements. Patients should be treated fairly and justly. The importance of informed consent is stressed. The author reminds us that food and water are symbolic sources of life, nurturing, and caring. They have significant spiritual and ritual connotations, different from any other aspect of medical treatment. Thus, end-of-life decisions that include the provision of nutrients can be the most difficult. The numerous case studies, tables, figures, and over 100 references provide important guidance in the handling of ethical issues.

Chapter 13 is authored by Joseph Boullata, who is also the co-editor of the first and second editions of *Handbook of Drug-Nutrient Interactions* that is included in the “Nutrition and Health” book series. Chapter 13 addresses the safe practices for both EN and PN. Safe practices in EN and PN involve a broad interplay between the healthcare providers, departments, and administrative structures, interacting to assure that processes and procedures in place are carried out during the administration of nutrition support therapy. The chapter emphasizes the importance of identifying safety issues and reducing error rates in the ICU that are relevant to delivery of EN and PN. The chapter includes a detailed discussion as well as relevant tables and figures that provide guidance concerning the nutrition support therapy process. The process includes a number of critical patient-focused steps from the initial patient assessment, to a prescriber’s order for a nutrition support regimen, the clinical pharmacist review of the orders, the preparation, labeling, and dispensing of the regimen, the administration of the nutrition support therapy to the patient, and finally subsequent monitoring of the patient with reassessment by the nutrition support service. This practice-oriented chapter reviews the documentation required at each step to assure that when errors are made, there is a mechanism to assess and correct processes going forward for the nutritionally supported patient in the ICU.

Another unique topic included in this comprehensive volume reviews the economic impact of nutritional support. Chapter 14 examines the evidence for the economic impact of providing nutrition to hospitalized patients so that clinicians can make a more informed decision when choosing the most appropriate intervention. The importance of using a multidisciplinary team approach for providing nutrition is discussed and suggestions for practice that can improve cost-effectiveness of providing nutrition support are included. The chapter includes a review of the literature concerning the costs associated with malnourished patients. There are also helpful appendices included in the chapter. The authors indicate that malnutrition in hospitalized patients is associated with both negative clinical and economic outcomes. Studies have demonstrated increased complications, increased length of hospital stay, increased readmissions, and increased risk of mortality. In addition, such patients require more healthcare resources compared to their counterparts without malnutrition. Provision of oral nutritional support and EN are both cost-effective in the critically ill patient in the ICU especially if EN can prevent the use of PN. The importance of the nutrition support team is emphasized.

The last two chapters examine areas where future research can be of value in providing novel nutritional modalities to the critically ill patient. Chapter 15 examines the role of the microbiome, the bacteria that inhabit the GI tract, as it relates to the provision of enteral and parenteral nutrition in the critically ill, including a discussion of current data, as well as areas for future study and intervention. The chapter includes data indicating that PN, which results in enteral deprivation, leads to a lack of microbiome diversity and poorer perioperative outcomes. Complications including anastomotic leak, wound infection, and bacteremia are more common in the PN-fed patients. Decreased microbial diversity is associated with poorer outcomes, particularly in the critically ill. PN secondarily depletes the nutrients needed by the gut bacteria, potentially leading to the loss of bacterial diversity. Future research may result in provision of beneficial intestinal bacteria to the PN patient. The last chapter on future research is authored by both volume editors. Areas for future research identified in this chapter include a determination of a clinically relevant and consistent definition of malnutrition including one for the critically ill patient with specific disease states such as cancer, obesity, pulmonary, kidney, gastrointestinal, and cardiovascular diseases. Research on the interactions between the immune system, the gut, and the microbiome and the impact of critical illness on the interactions with regard to nutritional needs is currently lacking, but the need for such data is great. Clinical studies to determine the best timing, mode of delivery, formulation contents and concentrations, drug-nutrient interactions, effects of aging, diabetes, and obesity are identified as major areas for focus.

The above description of the volume’s 16 chapters attests to the depth of information provided by the 26 well-recognized and respected chapter authors. Each chapter includes complete definitions of terms with the abbreviations fully defined for the reader and consistent use of terms between chapters. The volume includes 57 detailed tables and informative figures, several case studies, relevant

appendices, an extensive, detailed index, and more than 1250 up-to-date references that provide the reader with excellent sources of worthwhile information. Thus, the volume provides a broad base of knowledge concerning the pathology associated with critical illness and nutritionally relevant interventions that can enhance the potential for the patient's more healthful life.

In conclusion, *Nutrition Support for the Critically Ill* edited by David S. Seres, MD and Charles W. Van Way, III, MD provides health professionals in many areas of clinical research and intensive care unit practice with the most up-to-date, well-referenced volume on the importance of monitoring the nutritional status of the patient in the ICU regardless of cause from the day of admission through the remainder of their lifetime. Specific volume chapters carefully document the critical economic as well as clinical value of medical nutrition evaluation by a specialized ICU dietician/nutritionist as part of the nutrition support team, and review the treatment support and management of ICU patients who often have additional chronic diseases, such as diabetes and organ failures including the lung and/or liver. Each of these conditions is covered in depth in individual chapters. Unique chapters examine the nutritional requirements for the ICU patient who undergoes organ transplant, is obese, and who cannot consume food by mouth or through the enteral route. This volume will serve the reader as the benchmark in this complex area of interrelationships between acute, severe injuries due to accident or planned surgery, worsening of pre-existing conditions, and end stages of serious diseases such as cancer, and the determination of the appropriate nutritional intervention. Moreover, the critical importance of maintaining the microbiome within the gut even in the face of PN is discussed with the potential for future research in this important new area of clinical research. This comprehensive volume also includes a most sensitive and relevant chapter on the ethical considerations of nutritional support in the ICU including a discussion of end-of-life decision-making processes. The volume clearly delineates the complexities involved in the care of the nutritional needs of the critically ill patients so that medical students, nurses, dietitians, residents, fellows, as well as critical care specialists can better understand the interactions between malnutrition, increased risk of infection, inflammation, and stress responses. Unique chapters that examine the importance of safety and quality standards to improve patient outcomes following nutritional therapies are included. These chapters provide the health professional involved in the treatment of ICU patients with an enhanced understanding of the potential to stabilize the nutritional status of the critically ill patient. The editors are applauded for their efforts to develop the most authoritative resource in the field to date, and this excellent text is a very welcome addition to the Nutrition and Health Series.

Adrienne Bendich, PhD, FACN, FASN
Series Editor

About the Series Editor



Dr. Adrienne Bendich, PhD, FASN, FACN has served as the “Nutrition and Health” Series Editor for 20 years and has provided leadership and guidance to more than 200 editors that have developed the 70+ well-respected and highly recommended volumes in the series.

In addition to “**Nutrition Support for the Critically Ill**” edited by **David S. Seres, MD and Charles W. Van Way, III, MD**, major new editions published in 2012–2016 include the following:

1. **Nutrition in Cystic Fibrosis: A Guide for Clinicians**, edited by Elizabeth H. Yen, MD and Amanda R. Leonard, MPH, RD, CDE, 2016.
2. **Preventive Nutrition: The Comprehensive Guide for Health Professionals, Fifth Edition**, edited by Adrienne Bendich, PhD and Richard J. Deckelbaum, MD, 2016.
3. **Glutamine in Clinical Nutrition**, edited by Rajkumar Rajendram, Victor R. Preedy, and Vinood B. Patel, 2015.
4. **Nutrition and Bone Health, Second Edition**, edited by Michael F. Holick and Jeri W. Nieves, 2015.
5. **Branched Chain Amino Acids in Clinical Nutrition, Volume 2**, edited by Rajkumar Rajendram, Victor R. Preedy, and Vinood B. Patel, 2015.
6. **Branched Chain Amino Acids in Clinical Nutrition, Volume 1**, edited by Rajkumar Rajendram, Victor R. Preedy, and Vinood B. Patel, 2015.
7. **Fructose, High Fructose Corn Syrup, Sucrose and Health**, edited by James M. Rippe, 2014.
8. **Handbook of Clinical Nutrition and Aging, Third Edition**, edited by Connie Watkins Bales, Julie L. Locher, and Edward Saltzman, 2014.

9. **Nutrition and Pediatric Pulmonary Disease**, edited by Dr. Youngran Chung and Dr. Robert Dumont, 2014.
10. **Integrative Weight Management**, edited by Dr. Gerald E. Mullin, Dr. Lawrence J. Cheskin, and Dr. Laura E. Matarese, 2014.
11. **Nutrition in Kidney Disease, Second Edition**, edited by Dr. Laura D. Byham-Gray, Dr. Jerrilynn D. Burrowes, and Dr. Glenn M. Chertow, 2014.
12. **Handbook of Food Fortification and Health, volume I**, edited by Dr. Victor R. Preedy, Dr. Rajaventhana Srirajaskanthan, Dr. Vinood B. Patel, 2013.
13. **Handbook of Food Fortification and Health, volume II**, edited by Dr. Victor R. Preedy, Dr. Rajaventhana Srirajaskanthan, Dr. Vinood B. Patel, 2013.
14. **Diet Quality: An Evidence-Based Approach, volume I**, edited by Dr. Victor R. Preedy, Dr. Lan-Ahn Hunter, and Dr. Vinood B. Patel, 2013.
15. **Diet Quality: An Evidence-Based Approach, volume II**, edited by Dr. Victor R. Preedy, Dr. Lan-Ahn Hunter, and Dr. Vinood B. Patel, 2013.
16. **The Handbook of Clinical Nutrition and Stroke**, edited by Mandy L. Corrigan, MPH, RD, Arlene A. Escuro, MS, RD, and Donald F. Kirby, MD, FACP, FACN, FACG, 2013.
17. **Nutrition in Infancy, volume I**, edited by Dr. Ronald Ross Watson, Dr. George Grimble, Dr. Victor Preedy, and Dr. Sherma Zibadi, 2013.
18. **Nutrition in Infancy, volume II**, edited by Dr. Ronald Ross Watson, Dr. George Grimble, Dr. Victor Preedy, and Dr. Sherma Zibadi, 2013.
19. **Carotenoids and Human Health**, edited by Dr. Sherry A. Tanumihardjo, 2013.
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24. **Alcohol, Nutrition and Health Consequences**, edited by Dr. Ronald Ross Watson, Dr. Victor R. Preedy, and Dr. Sherma Zibadi, 2012.
25. **Nutritional Health, Strategies for Disease Prevention, Third Edition**, edited by Norman J. Temple, Ted Wilson, and David R. Jacobs, Jr., 2012.
26. **Chocolate in Health and Nutrition**, edited by Dr. Ronald Ross Watson, Dr. Victor R. Preedy, and Dr. Sherma Zibadi, 2012.
27. **Iron Physiology and Pathophysiology in Humans**, edited by Dr. Gregory J. Anderson and Dr. Gordon D. McLaren, 2012.

Earlier books included **Vitamin D, Second Edition**, edited by Dr. Michael Holick; “**Dietary Components and Immune Function**” edited by Dr. Ronald Ross Watson, Dr. Sherma Zibadi, and Dr. Victor R. Preedy; “**Bioactive Compounds and Cancer**” edited by Dr. John A. Milner and Dr. Donato F. Romagnolo; “**Modern Dietary Fat Intakes in Disease Promotion**” edited by Dr. Fabien De Meester, Dr. Sherma Zibadi, and Dr. Ronald Ross Watson; “**Iron Deficiency and Overload**” edited by Dr. Shlomo Yehuda and Dr. David Mostofsky; “**Nutrition Guide for Physicians**” edited by Dr. Edward Wilson, Dr. George A. Bray, Dr. Norman Temple, and Dr. Mary Struble; “**Nutrition and Metabolism**” edited by Dr. Christos Mantzoros; and “**Fluid and Electrolytes in Pediatrics**” edited by Leonard Feld and Dr. Frederick Kaskel. Recent volumes include “**Handbook of Drug-Nutrient Interactions**” edited by Dr. Joseph Boullata and Dr. Vincent Armenti; “**Probiotics in Pediatric Medicine**” edited by Dr. Sonia Michail and Dr. Philip Sherman; “**Handbook of Nutrition and Pregnancy**” edited by Dr. Carol Lammi-Keefe, Dr. Sarah Couch, and Dr. Elliot Philipson; “**Nutrition and Rheumatic Disease**” edited by Dr. Laura Coleman; “**Nutrition and Kidney Disease**” edited by

Dr. Laura Byham-Gray, Dr. Jerrilynn Burrowes, and Dr. Glenn Chertow; “**Nutrition and Health in Developing Countries**” edited by Dr. Richard Semba and Dr. Martin Bloem; “**Calcium in Human Health**” edited by Dr. Robert Heaney and Dr. Connie Weaver; and “**Nutrition and Bone Health**” edited by Dr. Michael Holick and Dr. Bess Dawson-Hughes.

Dr. Bendich is President of Consultants in Consumer Healthcare LLC and is the editor of ten books including “**Preventive Nutrition: The Comprehensive Guide for Health Professionals, Fifth Edition**” co-edited with Dr. Richard Deckelbaum (www.springer.com/series/7659). Dr. Bendich serves on the *Editorial Boards of the Journal of Nutrition in Gerontology and Geriatrics* and *Antioxidants* and has served as Associate Editor for *Nutrition* the International Journal, served on the Editorial Board of the *Journal of Women’s Health and Gender-Based Medicine*, and served on the Board of Directors of the American College of Nutrition.

Dr. Bendich was Director of Medical Affairs at GlaxoSmithKline (GSK) Consumer Healthcare and provided medical leadership for many well-known brands including TUMS and Os-Cal. Dr. Bendich had primary responsibility for GSK’s support for the Women’s Health Initiative (WHI) intervention study. Prior to joining GSK, Dr. Bendich was at Roche Vitamins Inc. and was involved with the groundbreaking clinical studies showing that folic acid-containing multivitamins significantly reduced major classes of birth defects. Dr. Bendich has coauthored over 100 major clinical research studies in the area of preventive nutrition. She is recognized as a leading authority on antioxidants, nutrition and immunity and pregnancy outcomes, vitamin safety, and the cost-effectiveness of vitamin/mineral supplementation.

Dr. Bendich received the Roche Research Award, is a *Tribute to Women and Industry* Awardee and was a recipient of the Burroughs Wellcome Visiting Professorship in Basic Medical Sciences. Dr. Bendich was given the Council for Responsible Nutrition (CRN) Apple Award in recognition of her many contributions to the scientific understanding of dietary supplements. In 2012, she was recognized for her contributions to the field of clinical nutrition by the American Society for Nutrition and was elected a Fellow of ASN. Dr. Bendich is Adjunct Professor at Rutgers University. She is listed in *Who’s Who in American Women*.

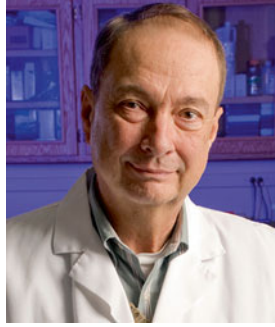
About the Volume Editors



David S. Seres, MD, ScM, PNS is Director of Medical Nutrition and Associate Professor of Medicine in the Institute of Human Nutrition, Columbia University Medical Center, New York, NY. Dr. Seres has 25 years' experience as a nutrition support specialist. He directs the nutrition support service, the medical school nutrition curriculum, and one of the few clinical nutrition fellowships for physicians in the USA. He was recipient of the 2014 Excellence in Nutrition Education Award from the American Society for Nutrition. Dr. Seres is also a clinical ethicist and a Columbia University/OpEd Project Public Voices Fellow.

Dr. Seres is currently a member of the Medical Advisory Board for Consumer Reports and has held numerous national leadership positions. He was Chair of Physician Certification for the National Board of Nutrition Support Certification, and Chair of the Medical Practice Section for the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). He is coauthor of multiple safety guidelines, chapters, editorials, and invited reviews, and appears frequently in the media advocating to consumers against dangerous foods, supplements, and nutritional practices.

Dr. Seres' research includes improving nutrition content in medical school curricula, the impact of feeding tube choice on patient outcomes and the indications for placing feeding tubes in patients placed in nursing homes, the risk of blood-stream infections in patients receiving parenteral nutrition, and metabolic derangements in acute illness.



Charles W. Van Way III, MD, FACS, FCCM, FCCP, FASPEN is Director of Metabolic Support at Truman Medical Center, and Emeritus Professor of Surgery at the University of Missouri, Kansas City. He has nearly 50 years of clinical experience in nutrition support, dating back to his surgical residency at Vanderbilt University. Although semi-retired, he maintains clinical practice in nutrition and critical care. He is the Director of the Shock Trauma Research Center of UMKC and continues research on nutrition support and on post-shock inflammation.

Dr. Van Way is a past President of the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) and has just finished 4 years as President of the A.S.P.E.N. Rhoades Research Foundation. He has been Editor in Chief of both the *Journal of Parenteral and Enteral Nutrition* and *Nutrition in Clinical Practice*. He has had many other leadership and editorial positions. He has more than 400 publications, most in peer-reviewed journals, including many editorials in regional and national publications.

Contents

| | |
|--|-------|
| Dedication | v |
| Foreword | vii |
| Preface | xi |
| Series Editor page | xiii |
| About the Series Editor | xix |
| About the Volume Editors | xxiii |
| | |
| 1 An Introduction to Malnutrition in the Intensive Care Unit | 1 |
| David S. Seres | |
| 2 The Immunological Role of Nutrition in the Gut | 9 |
| Rebecca A. Busch and Kenneth A. Kudsk | |
| 3 Assessment of the Patient | 37 |
| Marion F. Winkler, Kenneth A. Lynch, Jr., and Stephanie N. Lueckel | |
| 4 Timing and Indications for Enteral Nutrition in the Critically Ill | 55 |
| Philippa T. Heighes, Gordon S. Doig, and Fiona Simpson | |
| 5 Access and Complications of Enteral Nutrition Support for Critically Ill Patients | 63 |
| Tushar D. Gohel and Donald F. Kirby | |
| 6 Timing and Indication for Parenteral Nutrition in the Critically Ill | 81 |
| Jan Gunst and Michael P. Casaer | |
| 7 Access and Complications of Parenteral Nutrition | 99 |
| Dustin R. Neel | |
| 8 Surgical Intensive Care Considerations | 121 |
| Charles W. Van Way III | |
| 9 Major Infections and Sepsis | 141 |
| Eoin Slattery and David S. Seres | |
| 10 Organ Failure and Specialized Enteral Formulas | 157 |
| Ainsley Malone and Farshad Farnejad | |

11 Management of the Obese Patient 173
Roland N. Dickerson

12 Ethical Considerations in Nutrition Support in Critical Care 195
Albert Barrocas and Denise Baird Schwartz

13 Safe Practices for Enteral and Parenteral Nutrition 229
Joseph I. Boullata

14 The Economic Impact of Nutrition Support, and the Multidisciplinary Approach..... 243
Robert DeChicco and Ezra Steiger

15 Microbiome in the Critically Ill..... 259
Meredith Barrett and Daniel H. Teitelbaum

16 Future Research 269
David S. Seres and Charles W. Van Way, III

Index..... 277

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Chapter 1

An Introduction to Malnutrition in the Intensive Care Unit

David S. Seres

Keywords Malnutrition • Starvation • Hypoalbuminemia • Albumin • Cachexia • Catabolism • Muscle wasting • Nutritional deficiency • Kwashiorkor • Marasmus • Protein-calorie malnutrition • Nutrition support

Key Points

- Malnutrition refers to two distinct syndromes: one due to imbalance between intake and physiological need, and the other resultant from systemic inflammatory disease.
- Distinguishing between disease-related and starvation-related malnutrition best selects patients appropriate for nutritional intervention.
- Careful screening and identification of patients with malnutrition identifies those patients with high risk for hospital complications, prolonged length of stay, and mortality.
- Malnutrition due to imbalance may be reversed by nutritional supplementation.
- Malnutrition due to systemic illness does not respond to nutritional supplementation.
- Deficiency is not solely a low level of a nutrient. It is a pathological syndrome resulting from inadequate intake or altered physiology that responds to supplementation.
- Contrary to common wisdom, neither disease-related malnutrition nor kwashiorkor is a protein-deficiency state, in that deficient protein intake does not cause them, nor does protein supplementation improve them.

Introduction

A full understanding of both the cause and treatment of malnutrition in critically ill patients is crucial, and is the key to understanding the complex role of nourishing them. Malnutrition is highly predictive of morbidity and mortality in the ICU [1], so are feeding difficulty [2] and feeding efficiency (percent

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