Applied Nutrition in ICU Patients*

A Consensus Statement of the American College of Chest Physicians

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Abbreviations: BCAA=branched chain amino acids; EN=enteral nutrition; IBW=ideal body weight; PUFA=polyunsaturated fatty acids; R/Q=respiratory quotient

OUTLINE OF CONSENSUS STATEMENT ON NUTRITION
I. Introduction to the consensus statement
II. The consensus statement
   A. Malnutrition in critically ill patients
   B. General goals and principles
      1. General goals of nutrition support
      2. General principles of nutrition support
   C. Specific considerations
      1. The systemic inflammatory response syndrome (SIRS), with or without multiple organ dysfunction syndrome (MODS)
      2. Renal failure
      3. Liver failure
      4. Non-ARDS respiratory failure
      5. Obesity
      6. Preexisting malnutrition
      7. Diabetes mellitus
      8. Immunodeficiency states
      9. Geriatric patients
      10. Lymph fistulas

D. New developments: foods for special dietary purposes
   1. Glutamine
   2. Branched chain amino acids
   3. Peptides in enteral formulations
   4. Growth hormone
   5. Arginine
   6. Omega-3 polyunsaturated fatty acids (fish oils)
   7. Nucleic acids
   8. Nutrient combinations for modulation of immune function
   9. Glycerol
   10. Nutrients with antioxidant properties
   11. Short-chain fatty acids
   12. Fiber

INTRODUCTION TO THE CONSENSUS STATEMENT

Nutrition support is a routine part of ICU therapy. It is recommended to treat and prevent malnutrition and nutrient deficiencies and generally benefits patient outcomes, although adverse effects and complications of the therapy do occur. Because a large number of clinical studies of applied nutrition have been performed in ICU patients, a consensus panel was commissioned to summarize current knowledge and formulate recommendations.

The goals of the consensus process were to (1) define the clinical ICU settings where nutritional therapy benefits patient outcomes, (2) define the goals of nutrition therapy, and (3) identify the nutrient needs of ICU patients. The objectives of the process were to develop general guidelines for patient selection, timing and route of administration, nutrient use, and monitoring of the therapy. Clini-
cally relevant outcomes for nutrition therapy were evaluated and areas of current research that may have future clinical relevance were identified.

Three constraints were imposed on the consensus process: (1) to consider only adult patients, (2) to consider only patients whose acute disease was of sufficient magnitude to warrant admission and treatment in an ICU; and (3) to consider clinical settings requiring at least 4 days of ICU confinement. Generally, these patients require life support and are receiving mechanical ventilation; they also constitute the greatest mortality risk and the most intense use of ICU resources.1

Three information sources were used by the consensus participants: (1) an assessment of the peer-reviewed literature, with priority given to randomized, prospective clinical studies, then to retrospective clinical studies; (2) a compilation of the generally accepted knowledge in the field of nutrition; and (3) the experience of knowledgeable practitioners of nutrition therapy in ICU patients.

Research will continue in this area of therapy and updates to this consensus statement will be needed. This statement may be used as a resource for establishing guidelines for nutrition support and as a resource for quality management functions for institutions or individual practice settings.

The Consensus Statement

Malnutrition in Critically Ill Patients

Malnutrition is a disorder of body composition in which macronutrient and/or micronutrient deficiencies occur when nutrient intake is less than required, and which results in reduced organ function, abnormal results of blood chemistry studies, reduced body mass, and less optimal clinical outcomes. It is a common problem in critically ill patients that can be present upon admission to the ICU or can develop during the course of critical illness. Various disease processes common to the ICU patient result in changes in substrate metabolism that also lead to clinical manifestations of altered body composition and nutrient deficiencies.2 In malnutrition due to simple starvation or undernutrition, fat and protein are lost, but the loss of protein is minimized by reducing the need to use it as a source of energy (Appendix 2). Nitrogen loss is modified by mobilization of fat, and enhanced fat oxidation becomes a principal source of energy in the starving individual. Some protein wasting does occur despite the availability of fat, and it becomes markedly accelerated when fat stores are depleted. In critical illness with hypermetabolism, as in sepsis, accelerated protein catabolism occurs to provide energy and to support increased protein synthesis (Fig 1). With inadequate caloric intake, energy sources are derived from excessive protein breakdown and gluconeogenesis. Various protein “pools” can be depleted to provide fuel and metabolic substrate, including muscle and visceral protein. Thus, assessment of malnutrition in critically ill patients includes evaluation of clinical, anthropometric, chemical, and immunologic parameters reflecting altered body composition.3 It is important to note that currently there is no one readily available test that is both sensitive and specific for malnutrition in critically ill patients. All tests suffer from significant limitations and any application has to be considered in the light of those limitations.

Loss of body weight, which is universally coincident with protein caloric malnutrition, provides a readily accessible indication of altered nutritional status. Weight loss in excess of 10% ideal body weight (IBW) suggest malnutrition.4 Unfortunately, many critically ill patients are edematous and the measured weight may not reflect the real body cell mass.

Hepatic secretory proteins such as albumin, transferrin, retinol binding protein, and prealbumin are markers of visceral protein stores and are used as indicators of nutritional status. As these proteins have various half-lives, eg, albumin ($t_{1/2}=18$ days) and transferrin ($t_{1/2}=8$ days), they have variable sensitivity as predictors of nutritional status. Hepatic protein production, however, is influenced by numerous factors in addition to the nutritional status,
including disorders of hepatic function, protein losing states, and acute infection or inflammation. The frequent presence of these conditions in ICU patients limits the effectiveness of these proteins as markers of nutritional deficiency or the effectiveness of nutrition support.

**Anthropometry** involves measurement of skin folds, circumferences, and skeletal breadths to divide the body into compartments of fat, muscle tissue, and skeletal mass. The primary advantages of anthropometrics over more complex body composition measurements include simplicity, safety, cost, and widespread application. However, while techniques of measurement are standardized, interpretation of results remains controversial and of limited value in the acute ICU setting.

**Creatinine height index** is a theoretic estimate of lean body mass derived from measurement of the 24-h urinary creatinine excretion compared with standard values for a given height. Factors that influence creatinine excretion, therefore, complicate the interpretation of this index and include age, diet, exercise, stress, and renal disease.

**Cellular immunity or delayed cutaneous hypersensitivity** is commonly tested by recall to skin-test antigens such as Cándida, mumps, Trichophyton, and streptokinase-streptodornase. Depression of cellular immunity has been consistently associated with malnutrition and nutritional repletion is associated with improved immunocompetence. In ICU patients, the utility of skin testing is limited by a number of disease states and drugs associated with anergy, such as infection, malignancy, radiotherapy, chemotherapy, burns, other immunocompromising diseases, and the use of steroids and antirejection medications. Technical application and interpretation of skin tests in an ICU population remain difficult.

**Multiparameter nutritional indexes** have been proposed to overcome the sensitivity and specificity difficulties of single nutritional assessment tests. The prognostic nutritional index is a mathematical formulation combining measurements of serum albumin, triceps skinfold thickness, transferrin, and delayed hypersensitivity skin testing. Although the prognostic nutritional index can be a predictor of major morbidity in surgical patients, its utility in the ICU and in medical patients is less well evaluated.

**Muscle function tests** have been used as a marker of nutritional status. Clinical investigations have focused on assessment of adductor pollicis muscle, handgrip dynamometry, and respiratory muscle strength. Changes in twitch characteristics of the adductor pollicis muscle occur with stimulation of the ulnar nerve in malnourished patients. The lack of technical expertise and equipment limits widespread clinical application. Handgrip dynamometry can predict postoperative complications. Respiratory muscle strength as assessed by maximal airway or transdiaphragmatic pressures, endurance as assessed by maximal voluntary ventilation, and vital capacity measurements are reduced in malnourished patients. Limitations of these techniques in ICU patients are multiple and include, in the case of maximal voluntary ventilation and vital capacity, the need for an awake, alert patient. Metabolic factors such as hyperventilation, hypoxia, medications, and intrinsic muscle disease also complicate interpretation.

Newer more sophisticated methods of nutritional assessment being evaluated include nuclear magnetic resonance, whole body conductance and impedance, and neutron activation. Little data exist evaluating their utility in ICU patients.

In conclusion, multiple tests and combinations of tests are available to assess nutritional status. No simple recommendation can be given regarding the “best” test for nutritional assessment. Use of any of these methods can be appropriate, providing the limitations are clearly understood. Although not studied in ICU patients, it is important to note that data in hospitalized patients suggest that clinical assessment of nutritional status, including weight loss (>10% IBW), is as reliable an indicator of malnutrition as more complex tests of nutritional assessment.

**General Goals and Principles**

**General Goals of Nutrition Support:** This portion of the consensus document summarizes the general goals of nutrition support in ICU patients: (1) provide nutritional support consistent with the patient’s general condition, nutritional status, and available route of nutrient administration; (2) prevent or treat macronutrient and micronutrient deficiencies; (3) provide doses of nutrients compatible with existing metabolism; (4) avoid complications related to the technique of dietary delivery; and (5) improve patient outcomes such as those related to disease morbidity, eg, body composition, tissue repair, and organ function, and those affecting resource utilization, medical morbidities and mortalities, and subsequent patient performance.

**General Principles of Nutrition Support:** This portion of the consensus document summarizes the general nutrient requirements and principles of providing nutrition support in ICU patients. These general considerations may need to be modified in accord with the disease(s) present; modifications are presented in the section entitled “Specific Considerations.”
Macronutrients

(1) Total Calories: The existing body cell mass is a major determinant of the total caloric requirement. The total caloric requirement can either be estimated or directly measured. Whether precisely matching energy input with energy expenditure improves patient outcomes remains controversial. Calorie overload should be avoided, but energy should be administered to promote anabolic functions. Administering 25 total kilocalories per kilogram usual body weight per day (1 kg/d) appears to be adequate for most patients. The total calories should be administered in a volume consistent with the total fluid needs of the patient. In general, 1 mL of water is needed per kilocalorie administered.

(2) Glucose: 30 to 70% of the total calories administered per day can be given as glucose, ie, up to 2 to 5 g glucose per kilogram per day. The dose should be adjusted to maintain a blood glucose level <225 mg/dL, including administering regular insulin, if necessary.

(3) Fats: 15 to 30% of the total calories administered per day can be provided as fat. Omega-6 polyunsaturated fatty acid (PUFA) triglycerides should be provided in doses adequate to prevent essential fatty acid deficiency, ie, at least 7.0% of total calories. Medium-chain triglycerides can be used as a source of calories. The ratio of medium-chain triglycerides to long-chain triglycerides administered is dependent on the route of administration and on product availability.

(4) Protein Sources: 15 to 20% of the total calories administered per day can be given as protein or amino acids. The calorie-to-nitrogen ratio of the formulation is not a useful consideration in choosing protein sources. Initiation of therapy can be estimated at 1.2 to 1.5 g/kg/d and adjusted with periodic monitoring to promote nitrogen retention and support protein synthetic functions. Considerations for a decrease in dosing include a rising BUN level that exceeds 100 mg/dL, and a rising blood ammonia level that is associated with clinical encephalopathy.

Micronutrients

The precise requirements for vitamins, minerals, and trace elements have yet to be determined. Potassium, magnesium, zinc, and phosphate should be provided in doses adequate to maintain normal serum levels. Normal serum levels will vary with the laboratory in which the measurement is performed. Useful information on micronutrient administration is presented in the material on micronutrients in the “Background and Supporting Information” section of this document. Normal values are summarized in Table 1.

Route of Administration

(1) The Enteral Route: The enteral route is pre-
ferred for nutrient administration. Use of the enteral route is associated in clinical studies with preservation of gut integrity, barrier and immune functions, and reductions in infectious complications. Current data support the initiation of enteral nutrition (EN) as soon as possible after resuscitation. Intragastric feeding requires adequate gastric motility. In general, a gastric residual of >150 mL will require a moderation of the infusion rate, consideration of supplemental IV nutrition, or the use of small bowel feedings. Small bowel feedings can usually be performed, even in the presence of gastric atony and colonic ileus. Concomitant gastric decompression may be required. The role of agents designed to improve gastric and intestinal motility is not yet established, eg, cisapride, erythromycin.

The presence of bowel sounds and the passage of flatus or stool are not necessary for the initiation of enteral feedings, particularly when feedings are administered distal to the pylorus. Increasing abdominal distention necessitates cessation of the feedings and a medical evaluation. Small bowel feedings, in general, are efficacious in the presence of mild or resolving pancreatitis and low output enterocutaneous fistulas (<500 mL/d) and can be administered until clinical intolerance occurs.

Diarrhea may occur with the administration of enteral feedings. It is usually secretory and is generally not an indication to discontinue enteral feedings. If it exceeds 1,000 mL/d, an evaluation is required. If a relevant medical or surgical cause is not found, including Clostridium difficile enterocolitis, antidiarrheal agents may be used.

(2) The Parenteral Route: The parenteral route of
nutrient administration is recommended when the enteral route is not accessible or usable, or as a supplement to enteral feeding if adequate nutrient administration is not possible via the enteral route alone. The use of the parenteral route is associated with an increased incidence of infectious complications, including the line access used for administration, and a significant incremental cost. Parenteral formulations are not as nutritionally complete as enteral formulations. However, the achievement of nutritional goals is more often attained by the parenteral route.

Strict adherence to administration protocols can reduce the complication rate. This is particularly so for central line care. Central lines for feeding must be placed and cared for with strict aseptic technique and used with limited interruption. Implanted, permanent lines are not recommended in the acute ICU setting. Consideration should be given to the use of peripheral indwelling central catheters lines.

**Monitoring:** Monitoring is essential to minimize complications and maximize the benefits of nutrition support.

1. Avoid overfeeding.
   - Adhere to the general guidelines as presented.
   - Although generally not necessary if the general guidelines of nutritional support are followed, expired gas analysis may be useful in this assessment; a respiratory quotient (R/Q) >1 generally indicates overfeeding; increased CO₂ production is present in R/Qs that increase from the 0.80 to 1.0 range.
   - A reduction of total calorie (glucose and fat) loads to decrease carbon dioxide production may be beneficial in parenterally fed patients with respiratory compromise.

2. Promote nitrogen retention and avoid protein overload.
   - The periodic assessment of nitrogen balance can be useful in adjusting the dose of protein (amino acids). Measurements every 5 to 7 days are useful for this purpose.
   - Excessive prerenal azotemia from protein (amino acid) administration is an indication to decrease nitrogen intake. BUN levels in the ≤100 mg/dL range are generally well tolerated.
   - Special formulations for acute renal failure (serum creatinine concentration elevated to twice normal range) do not benefit patient outcomes.
   - Consideration should be given to using dialytic (dialysis or the various forms of continuous hemofiltration) therapy to meet the goals of nutrition support in patients with renal failure.

3. Monitoring triglyceride clearance is recommended.

(a) Precise definitions of excessive levels of plasma triglycerides are difficult; a triglyceride level of ≤500 mg/dL with continuous fat infusion is accepted by some critical care physicians.

(b) Weekly monitoring of visceral protein levels in plasma may be useful, eg, transferrin or prealbumin. However, in ICU settings, their levels may not be indicative of the response to feeding and do not appear to correlate well with patient outcomes. The measurement of serum albumin level is generally not useful in the assessment of the response to nutrition support in these acute settings.

(c) Adequate monitoring of fluid and electrolyte status is necessary, particularly for potassium, phosphate, magnesium, calcium, and zinc. Serum levels well within the normal range should be maintained.

(d) Vitamin and trace element levels.
   - Routine monitoring is probably not useful.
   - Monitoring on a selected case basis where deficiency states are clinically suspected is encouraged.

(e) Weekly assessment of liver function with standard laboratory tests should be performed. Abnormalities in the results of standard tests of liver function are generally not an indication for liver specific nutrition (ie, use of modified amino acid formulas designed for liver failure).

**Specific Considerations**

This portion of the consensus document summarizes alterations of the general principles that result from the disease(s) that may be present in ICU patients. More than one disease is frequently present in an individual patient. Practitioners should start with the general principles of nutrition support and then modify the nutrients administered as necessary for the disease(s) that are present. Whenever a question arises, consultation with a nutrition practitioner or your nutrition support service is advised.

**The Systemic Inflammatory Response Syndrome, With or Without Multiple Organ Dysfunction Syndrome:** The metabolism in systemic inflammatory response syndrome is characterized by increased total caloric requirements, hyperglycemia, triglyceride intolerance, increased net protein catabolism, and increased macronutrient and micronutrient requirements. Caloric requirements may need to be increased 10 to 20%. Hyperglycemia, even in the absence of diabetes mellitus, is frequently present. When the blood glucose level exceeds 225 mg/dL, glucose loads must be reduced and/or regular insulin administration begun to maintain a blood glucose level under 225 mg/dL. The increased net protein catabolism necessitates an increase in protein admin-
istration. In general, nitrogen retention is promoted with 1.5 to 2.0 g/kg/d of protein (amino acids), not to exceed 2.2 g/kg/d.

Hypertriglyceridemia with lipemic serum may occur. If serum lipemia is not present, the general principles for fat administration can be used. If serum lipemia is present and the serum triglyceride level exceeds 500 mg/dL, total calories and/or the dose of omega-6 PUFA triglyceride should be reduced. The fat dose can be reduced by one third and the glucose load can be reduced to as low as 100 g/d. If the lipemia persists, the duration of the fat infusion can be increased up to 24 h per dose and/or heparin sodium (1 U/mL) can be given with the infusion. Once the triglyceride intolerance has abated, the doses of glucose and fat can be increased and the presence of lipemia reassessed.

Requirements for micronutrients are also increased. In addition, there may be excessive losses of potassium, zinc, magnesium, calcium, and phosphorus. Serum levels need to be more closely monitored and maintained within the normal range.

Renal Failure: Renal failure is accompanied by intolerance to fluids (oliguric/anuric form) and a rise in the plasma levels of potassium, magnesium, and phosphate. Frequent monitoring of these analytes is needed and the amounts administered reduced to maintain appropriate plasma levels. Diuretics are very useful in maintaining these balances; dialytic therapy may also be necessary to achieve appropriate nutritional support.

As opposed to chronic renal failure, there is no need to alter the amount of protein (amino acid) administered to patients with acute renal insufficiency. There is also no demonstrable advantage to alter the composition of the protein (amino acid) administered, e.g., by administering just essential amino acids. In patients with chronic renal insufficiency, protein (amino acid) dose of 0.5 to 0.8 g/kg/d is associated with preservation of renal function; and maintaining an arterial blood pH of >7.35 is associated with reduced net catabolism.

The consequences of dialytic therapy also need to be considered. Peritoneal dialysis fluid contains glucose, the amount of which needs to be considered in the determination of glucose and total calorie dosing. Peritoneal dialysis also removes amino acids, frequently in the range of 40 to 60 g/d. Hemodialysis and hemofiltration remove amino acids in the range of 3 to 5 g/h. These losses need consideration when adjusting the protein (amino acids) administered.

Liver Failure: Patients with liver failure as a single organ failure, e.g., cirrhosis, may be hypermetabolic. This determination needs to be made. Most patients will have increased losses of potassium, magnesium, and zinc and may be treated with fluid restriction for the presence of significant ascites. Close attention to fluid and electrolyte management is necessary.

Encephalopathy frequently accompanies liver failure. Some protein should be provided during this time. The dose of protein is reduced to the 1.0 to 1.3 g/kg range. If encephalopathy worsens or does not improve, or nutritional requirements are not met, consideration should be given to the use of enteral or parenteral products specifically designed for isolated liver failure. Generally, these products have an increased content of the branched chain amino acids (BCAA) and a reduced amount of the aromatic and sulfur-containing amino acids. The use of these preparations in settings other than isolated liver failure, e.g., multiple organ dysfunction syndrome in the absence of underlying cirrhosis, is not recommended.

There is no consensus on the nutritional management of fulminant liver failure resulting from viral hepatitis or drugs.

Non-ARDS Respiratory Failure: Most patients with isolated respiratory failure can be treated by applying the general principles for nutrition support. With current product formulations, the calorie-to-nitrogen ratio is not a major consideration. The major problem derives from overfeeding, i.e., an excess of total calories, either as carbohydrate or fat, or both. If overfeeding is believed to be a clinical problem, or if there is difficulty in weaning a patient from the ventilator, expired gas analysis with a determination of energy expenditure and the R/Q can be useful in management. An R/Q over 1 usually indicates overfeeding. Additionally, a higher R/Q indicates increased carbon dioxide production. An R/Q in the 0.85 to 0.90 range in these settings is reasonable. A carbon dioxide production of 3 to 5 mL/kg or more is believed to be excessive.

The administration of protein (amino acids) also increases oxygen consumption demands. In ICU patients, it is difficult to predict this effect. Oxygen consumption demand may be increased 15 to 20%. In general, this increased demand for oxygen is well tolerated and usually not an indication for reducing protein (amino acid) intake. Some experimental work also indicates that the BCAA may stimulate the respiratory center and improve the function of the muscles of respiration.

Obesity: The dilemma in obesity is in judging the energy and nutrient requirements. For purposes of this consensus document, obesity is defined as a body mass index over 25. Nutrient needs can be effectively based on the ideal weight for height.

Preexisting Malnutrition: For this consensus document, significant preexisting malnutrition is defined as a body mass index under 16. When it is present, nutrition support should be initiated as soon as
possible after admission to the ICU when nutrition support has become a major consideration in the therapy for the patient, eg, following resuscitation.

Refeeding patients with this degree of malnutrition may be associated with a number of refeeding syndromes, including excessive salt and fluid retention and dysrhythmias. Close attention to fluid and electrolyte management and ECG monitoring is necessary in the early stages of refeeding.

The initial estimates of nutrient requirements should be based on the existing body weight appropriately reduced for the estimated amount attributed to edema, ascites, and pleural effusions. After 7 to 10 days, nutrient requirements can be based on the IBW.

Diabetes Mellitus: Diabetes mellitus is common in ICU patients. Management of blood glucose level is essential for effective nutrition support. Close adherence to the general principles of glucose administration and monitoring will result in the successful treatment of most patients. Consensus does not exist on the most appropriate route of insulin administration. Options for regular insulin administration include the following: sliding scale, placing insulin in the parenteral nutrition administration container, or the use of a separate insulin infusion. In all cases, the goal is to maintain blood glucose level under 225 mg/dL.

Immunodeficiency States
(a) AIDS
At this time, close adherence to the general principles of nutrition support is recommended.
(b) Bone Marrow Transplantation
In addition to optimizing the general principles of nutrition management, a few studies have observed improved patient outcomes with the use of supplemental glutamine by the IV route. Doses in the range of 0.5 g/kg/d of glutamine have been used in these patients.
(c) Surgery, Trauma, Sepsis
In patients with systemic inflammatory response syndrome, who frequently have prolonged ICU stays, EN within 24 to 72 h of injury has been associated with significant reductions in infectious complications. Enteral formulas have been used with such agents as fish oil, arginine, and uracil as ribonucleic acid have been associated with significant reductions in hospital length of stay and infectious complications.

The dose of omega-6 PUFA triglycerides should be reduced, but not lower than that necessary to prevent essential fatty acid deficiency—ie, 7% of the total calories. Doses of 1 g/kg/d are well tolerated.

Geriatric Patients: For this consensus document, geriatric patients are defined as those patients who are 80 years of age or older. They require close attention to monitoring in their nutritional management; otherwise, the general principles of nutrition management can be applied.

Lymph Fistulas: When chylothorax is present, the use of total parenteral nutrition with IV fat is recommended. Otherwise, the general principles of nutrition support apply.

New Developments: Foods for Special Dietary Purposes
In addition to the role of macronutrients and micronutrients in the general nutrition support of ICU patients, specific nutrients are being evaluated for their individual effects on specific metabolic functions. These effects are being evaluated with doses that exceed those used in the general nutritional therapy of ICU patients. These potential macronutrients are provided in a setting of balanced nutritional support.

Glutamine: Glutamine is an amino acid that participates in a variety of metabolic processes, including the following: ammonia and hydrogen ion excretion in the kidney; the immune response; purine and pyrimidine synthesis; and the synthesis of glutathione. During catabolic states, it is mobilized in increased amounts from peripheral tissues such as skeletal muscle. Whether administering glutamine in increased quantities in catabolic states improves patient outcomes remains to be determined. Up to 0.5 g/kg/d has been used in clinical settings.

Branched Chain Amino Acids: The BCAA—leucine, isoleucine, and valine—are essential amino acids required for protein synthetic functions. Given in a balanced amino acid formulation at a dose of 0.5 to 1.2 g/kg/d of branched chain, they can improve nitrogen retention with reduced ureagenesis and increased protein synthetic functions relative to standard amino acid formulations. Their precise role in promoting improved patient outcomes remains to be defined.

Peptides in Enteral Formulations: Providing protein as peptides in enteral formulas may enhance enteral protein absorption. Their role in improving patient outcomes remains to be defined.

Growth Hormone: When growth hormone is administered, a variety of metabolic effects may be observed, including increased fat oxidation, an increased rate of protein synthesis, and improved immune responsiveness. Its effects on patient outcomes in adult ICU patients remain to be defined.

Arginine: Arginine is an amino acid that participates in a variety of metabolic functions, including nitric oxide and urea synthesis, lymphocyte proliferation, and wound healing. Its dosing and its role in improving outcomes in ICU patients remain to be
defined. Doses of up to 30 g/d have been used in adult postoperative patients.

*Omega-3 PUFA (Fish Oils):* Omega-3 PUFA have no established requirement in ICU patients. They are under clinical investigation as immune modulating and anti-inflammatory agents. Doses of up to 3 to 5 g/d in oil (eg, menhaden oil, canola oil) have been used in critically ill patients and/or patients with sepsis.

*Nucleic Acids: A nutritional requirement for nucleic acids has not been established. A number of nutrient roles of nucleic acids are being investigated. These roles include proliferation of intestinal crypt cells, lymphocyte proliferation, and cellular DNA and RNA synthesis.

*Nutrient Combinations for Modulation of Immune Function: Combinations of nutrients with immune function activity—arginine, fish oil, and nucleic acids—are being evaluated as components of balanced EN in patients who are immune suppressed following trauma, infection, and other forms of tissue injury. Several clinical studies have observed improvements in in *vitro* tests of lymphocyte function, a reduction in postoperative complications such as organ failure and infection, and a reduction in hospital length of stay.

*Glycerol:* Glycerol has been used as an alternative, noninsulinogenic carbohydrate source. It has been observed to have protein-sparing activity when given in combination with amino acids. This combination can be given by peripheral vein. Its role in improving outcomes in ICU patients remains to be defined.

*Nutrients With Antioxidant Properties: Nutrients with antioxidant properties include selenium, vitamins C and E, and beta-carotene. With the exception of beta-carotene, these are essential nutrients. Their antioxidant properties are being evaluated experimentally. In metabolic stress models, such effects as decreased pentane production have been observed. Their role in ICU patients remains to be clarified.

*Short-chain Fatty Acids:* No specific requirement for short-chain fatty acids has been established. These endogenous products of fiber fermentation are important for colonocyte integrity and function. A beneficial effect has been observed when they are given via enema in patients with acute colitis and in the clinical setting of diversion colitis. Their role in ICU patients remains to be defined.

*Fiber:* Fiber as a component of EN products may have beneficial effects of colonocyte function. Its role in the nutritional therapy of ICU patients remains to be defined.

**APPENDIX 1: THE NUTRITION CONSENSUS GROUP**
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**APPENDIX 2: THE HARRIS-BENEDICT EQUATION**

\[ \text{Women: } \text{BEE} = 655 + (9.6 \times \text{weight in kg}) + (1.7 \times \text{height in cm}) - (4.7 \times \text{age in years}) \]

\[ \text{Men: } \text{BEE} = 66 + (13.7 \times \text{weight in kg}) + (5 \times \text{height in cm}) - (6.8 \times \text{age in years}) \]
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Selected Readings

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