

Current perspective for tube feeding in the elderly: from identifying malnutrition to providing of enteral nutrition

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Abstract: With the number of individuals older than 65 years expected to rise significantly over the next few decades, dramatic changes to our society and health care system will need to take place to meet their needs. Age-related changes in muscle mass and body composition along with medical comorbidities including stroke, dementia, and depression place elderly adults at high risk for developing malnutrition and frailty. This loss of function and decline in muscle mass (ie, sarcopenia) can be associated with reduced mobility and ability to perform the task of daily living, placing the elderly at an increased risk for falls, fractures, and subsequent institutionalization, leading to a decline in the quality of life and increased mortality. There are a number of modifiable factors that can mitigate some of the muscle loss elderly experience especially when hospitalized. Due to this, it is paramount for providers to understand the pathophysiology behind malnutrition and sarcopenia, be able to assess risk factors for malnutrition, and provide appropriate nutrition support. The present review describes the pathophysiology of malnutrition, identifies contributing factors to this condition, discusses tools to assess nutritional status, and proposes key strategies for optimizing enteral nutrition therapy for the elderly.

Keywords: sarcopenia, home enteral nutrition, elderly, malnutrition, protein

Introduction

Advancements in health care have contributed to longevity. The number of individuals aged ≥ 60 years is expected to rise from 800 million to 2 billion, reaching 22% of the total world population over the next 40 years.¹ Despite being the healthiest group in human history (average life expectancy for someone in their sixties is now longer by >16 years in many developed countries), the elderly are a heterogeneous group, with a high prevalence of malnutrition, sarcopenia, and frailty.² In addition, the elderly have an increased risk for comorbid conditions, such as stroke, dementia, cancer, and heart disease, that predispose them to develop malnutrition.^{3,4} The prevalence of nutritional deficiency in the elderly is 15% in ambulatory outpatients, 25%–60% in institutionalized patients, and 35%–65% in hospitalized patients.^{5–7} In order to meet the nutritional needs of this population, health care providers will require skills for recognizing and managing malnutrition. This narrative review describes the pathophysiology of malnutrition, its contributing factors, tools by which to assess the condition, and options for maximizing enteral nutrition (EN) in the elderly.

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Pathophysiology of malnutrition and sarcopenia in the elderly

Frailty is defined as a clinically recognizable state of increased vulnerability from aging-associated decline in reserve and function across multiple physiological systems such that the ability to cope with acute stressors is comprised (Table 1).⁸ Elderly individuals are at the greatest risk of developing frailty due to a number of age-related physiological and functional changes. Loss of function and decline in muscle mass (ie, sarcopenia) can be associated with reduced physical mobility and ability to perform tasks of daily living, which place the elderly at an increased risk for falls, fractures, and subsequent institutionalization, leading to a decline in the quality of life and increased mortality.^{9,10} Muscle loss typically begins in the fifth decade of life and proceeds at a rate of ~0.8% loss per year. Muscle loss precedes declines in muscle force and performance.^{11,12} An estimated 200 million people worldwide will acquire sarcopenia by the year 2050, making it paramount that we address it during every patient encounter.

The etiology of sarcopenia is multifactorial, with two key modifiable factors being physical inactivity and reduced dietary protein intake. As an example, a single episode of resistance training can lead to an increase in muscle protein synthesis (MPS) that persists up to 48 hours.¹³ On the other hand, a 2-week reduction in physical activity (~76% reduction in habitual step count) can result in a 26% attenuation of MPS and reduction in muscle mass.¹⁴ Similarly, increasing dietary protein enhances MPS through an anabolic response via feeding, leading to a 300% increase in the rate of MPS and a 50% reduction in muscle protein breakdown (MPB).¹⁵⁻¹⁷ The increase in MPS returns to preprotein intake levels soon afterward, despite there being increased availability of plasma and muscle amino acids. Mammalian target of rapamycin complex 1 (mTORc1) may play a key signaling role for protein synthesis. In one study, a rising MPS rate

was associated with mTORc1 substrate phosphorylation in eight healthy men provided 48 g of whey protein.¹⁶ On the contrary, administration of rapamycin (specific inhibitor of mTORc1) reduces both MPS and activation of mTORc1 signaling proteins during essential amino acid (EAA) administration.¹⁸

Aging reduces MPS response, a phenomenon termed anabolic resistance. Moore et al¹⁹ showed that although there was no difference in baseline MPS rates between young and elderly healthy subjects, the quantity of protein intake to maximally stimulate MPS was 68% greater in the elderly, as compared with younger subjects when expressed relative to total body mass and 140% higher when expressed relative to lean body mass. The maximum MPS rate was similar between young and healthy elderly subjects, suggesting that healthy elderly subjects had retained MPS capability under the optimal protein dose. Other factors associated with anabolic resistance include a decrease in physical activity, an increase in splanchnic first-pass amino acid extraction (or sequestration), chronic subclinical inflammation, and dysregulation of intracellular signaling.^{14,19-22}

Risk factors for the development of malnutrition and sarcopenia

Dysphagia, or difficulty in swallowing, contributes significantly to the development of malnutrition in the elderly (Table 2). Studies report 13%–38% of elderly living independently may have dysphagia.^{3,23} The prevalence of dysphagia is higher in elderly patients admitted to the hospital (30%), after a stroke (64%), and in nursing home residents (68%).²⁴⁻²⁶ The etiology of dysphagia is multifactorial and includes age-related changes in muscle function and predisposing (acquired) conditions, such as stroke and dementia. Age-related decreases in muscle mass and connective tissue elasticity may lead to subtle slowing of the swallowing process with a reduction in the efficiency of

Table 1 Definitions

Malnutrition – diagnosed if two out of six clinical criteria are met

- Insufficient energy intake
- Weight loss
- Loss of muscle mass
- Loss of subcutaneous tissue
- Localized or generalized fluid accumulation
- Diminished functional capacity

Sarcopenia – decline in muscle mass with the loss of function

Frailty – clinically recognizable state of increased vulnerability from aging-associated decline in reserve and function across multiple physiological systems

Table 2 Factors contributing to malnutrition, frailty, and sarcopenia in the elderly

- Age-related loss of muscle mass
- Physical inactivity
- Reduced dietary protein intake
- Anabolic resistance
- Dysphagia
- Comorbidities – CVA, dementia, IBD, HIV, COPD, RA, and cancer
- Alcohol abuse
- Depression
- Lack of social support, isolation
- Financial limitations

Abbreviations: COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; IBD, inflammatory bowel disease; RA, rheumatoid arthritis.

swallowed materials passing through the upper digestive tract.²⁷ These processes contribute to an increased frequency of postswallow residue as well as penetration of unswallowed content into the upper airway. Although physiology studies suggest altered function of the gastrointestinal tract with aging, the elderly should not experience dysphagia based solely on aging alone in the absence of a disease process. Dysphagia is particularly common after a stroke, with estimates suggesting that 30%–65% of patients are acutely affected, and many have persistent swallowing difficulties after 6 months.^{3,28} The combination of dysphagia and stroke limits volitional macro- and micronutrient intakes, which increase the risk of malnutrition.²⁹

Dementia is another major risk factor for malnutrition (Table 2). The prevalence of dementia increases from 2%–3% in those aged 70–75 years to 20%–25% in those aged ≥ 85 years.³⁰ The prevalence of dementia is estimated to double by year 2040, with 81 million people being affected.³¹ Dysphagia is present in up to 45% of patients with dementia. Dementia-related cognitive and motor deficits and subsequent difficulties in self-feeding and loss of appetite contribute to malnutrition.^{3,32,33}

In addition, a number of disease processes contribute to malnutrition and sarcopenia (Table 2). Examples include inflammatory bowel disease, human immunodeficiency virus or acquired immunodeficiency syndrome, chronic obstructive pulmonary disease (COPD), rheumatoid arthritis, alcohol abuse, and cancer (especially when associated with cachexia). Cachexia is a complex metabolic condition associated with systemic inflammation from an underlying illness and can be associated with a significant loss of muscle mass with or without loss of fat mass.³⁴ Although the exact inflammatory mechanism is not known, increased circulating levels of interleukin-6 (IL-6) and tumor necrosis factor have been implicated. The systemic inflammation that accompanies cachexia seems to selectively target skeletal muscle, often leading to exaggerated or accelerated loss of skeletal muscle, which is mechanistically different from weight loss associated with malnutrition.^{34,35}

Psychosocial conditions are just as important for the development and management of malnutrition. Psychosocial pathology contributes to the development of malnutrition, and psychosocial pathology management plays a key role in the successful implementation of nutrition support. Careful assessments should be made for factors that can interfere with the acquisition and provision of EN, including lack of social support, financial limitations, and depression.^{36–38} Social isolation and poor finances can have a substantial

impact on elderly meal consumption. One study showed that meals consumed in an elderly group setting were 75% greater than meals consumed alone.³⁶ For elderly patients without volitional intake requiring EN, cultural and personal perceptions of “artificial” nutrition should be identified and clarified to promote enteral feeding.³⁹

Assessment for malnutrition

Defining malnutrition

The biggest challenge associated with assessment for malnutrition is agreement upon the definition of malnutrition and which clinical variables are the most important for its identification (Table 3).^{36,40} Despite expert disagreement, nutrition societies including the American Society for Parenteral and Enteral Nutrition (ASPEN) and the Academy of Nutrition and Dietetics (AND) have developed a consensus statement defining malnutrition based on several causal factors and taking into consideration acute and chronic illnesses.⁴¹ ASPEN and AND categorize malnutrition as either moderate or severe while acknowledging the difficulty differentiating mild from moderate degrees of malnutrition. Guidelines recommend a diagnosis of malnutrition if two of the following six clinical criteria are met (Table 1): 1) insufficient energy intake, 2) weight loss, 3) loss of muscle mass, 4) loss of subcutaneous fat, 5) localized or generalized fluid accumulation, and 6) diminished functional capacity determined by handgrip dynamometry.

Table 3 Tools to assess nutritional status

| |
|---|
| Anthropometric measures |
| BMI |
| Usual BW |
| Actual BW |
| Ideal BW |
| Height |
| Waist circumference |
| Mini Nutritional Assessment |
| Food intake |
| Weight loss |
| Mobility |
| BMI |
| Psychosocial stress, dementia, depression |
| DXA |
| CT |
| BIA |
| Nutritional risk |
| NRS-2002 |
| NUTRIC score |

Abbreviations: BIA, bioelectric impedance analysis; BMI, body mass index; BW, body weight; CT, computed tomography; DXA, dual-energy X-ray absorptiometry; NRS, Nutritional Risk Score; NUTRIC, Nutrition Risk in Critically Ill.

Hospital-based assessment of nutritional risk

Critically ill patients are at particular risk for malnutrition. Not all critically ill patients are alike, and it is also important to identify which patients may benefit from aggressive nutrition support. A number of validated risk scores have been developed and validated to identify the “nutritional risk” in the critically ill, which is the risk of acquiring complications as a consequence of insufficient nutrition. One tool is the Nutrition Risk in Critically Ill (NUTRIC) scoring system, which uses the following six variables to calculate a risk score: age, Acute Physiology and Chronic Health Evaluation (APACHE) II, Sequential Organ Failure Assessment, number of comorbidities, days from hospital to intensive care unit (ICU) admission, and IL-6 level.⁴² The NUTRIC score ranges from 0 to 10 points, with scores between 6 and 10 being associated with an increased risk for adverse outcomes (mainly mortality) and associated with improvement with aggressive nutrition therapy, as compared with lower scores. The difficulty obtaining IL-6 levels at most institutions called for the development of a modified NUTRIC score, which has been revalidated (without IL-6) and has shown that the odds of mortality at 28 days were 1.4 times greater for every point increase in the score.⁴³ NUTRIC score ≥ 5 with nutritional adequacy was associated with improved 28-day and 6-month mortalities, as compared with those with NUTRIC ≥ 5 and nutritional inadequacy (Table 4). In fact, for patients with a NUTRIC score of 6–9, each 25% increase in the percentage of caloric prescription achieved was associated with a reduced hazard rate (HR) of death (0.82).

The Nutrition Risk Score (NRS)-2002 is another nutritional risk assessment tool and has been validated in multiple populations including hospitalized elderly patients (Table 4).^{36,44–46} The initial screen focuses on the following four components: body mass index (BMI) < 20 kg/m², loss of weight in the previous 3 months, decreased nutritional intake, and severe illness.⁴⁷ If any of these factors are present, a final screening for impaired nutritional status and severity of disease is performed. Two scores are assigned and then added together. A nutrition adequacy score (0–3) is assigned based on recent weight loss, decreased oral intake, and low BMI. The disease severity score (0–3) is assigned based on the examples of increasingly severe disease processes such as hip fracture, COPD, and critical illness (APACHE II score > 10). Finally, the NRS-2002 takes into account age and adds one point for age > 70 years. A total NRS-2002 score of ≥ 3 suggests nutritional risk, indicating the need to optimize nutrition support.

Table 4 Nutritional risk screening and NUTRIC score

| (A) Nutritional risk screening 2002 | | |
|--|---|---|
| Score | Impaired nutritional status | Severity of disease |
| 0 – absent | Normal nutritional status | Normal nutritional requirements |
| 1 – mild | Weight loss $> 5\%$ in 3 months | Hip fracture |
| | Or Food intake $< 50\%$ – 75% of normal requirement in the preceding week | Chronic diseases (cirrhosis, COPD, hemodialysis, diabetes, oncology, and so on) |
| 2 – moderate | Weight loss $> 5\%$ in 2 months | Major abdominal surgery, stroke, severe pneumonia, hematologic malignancy |
| | Or BMI 18.5–20.5 kg/m ² + impaired general condition | |
| | Or Food intake 25%–50% of normal requirement in the preceding week | |
| 3 – severe | Weight loss $> 5\%$ in 1 month | Head injury |
| | Or BMI < 18.5 kg/m ² + impaired general condition | Bone marrow transplant ICU patient (APACHE score > 10) |
| | Or Food intake 0%–25% of normal requirement in the preceding week | |
| | | |
| (B) NUTRIC score | | |
| Score variables | Range | Points |
| Age (years) | < 50 | 0 |
| | 50– < 75 | 1 |
| | ≥ 75 | 2 |
| APACHE II score | < 15 | 0 |
| | 15– < 20 | 1 |
| | ≥ 20 | 2 |
| SOFA score | < 6 | 0 |
| | 6– < 10 | 1 |
| | ≥ 10 | 2 |
| Number of comorbidities | 0–1 | 0 |
| | ≥ 2 | 1 |
| Days from hospital to ICU admit | 0– < 1 | 0 |
| | ≥ 1 | 1 |

Note: To calculate the total score, first, find the score (0–3) for impaired nutritional status and severity of disease; second, add the two scores for a total score; third, if age is ≥ 70 years, add one point to the total score to correct for the frailty of the elderly; and fourth, if age-corrected total is ≥ 3 , start nutritional therapy.

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; BMI, body mass index; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit; NUTRIC, Nutrition Risk in Critically Ill; SOFA, Sequential Organ Failure Assessment.

Ambulatory assessment of malnutrition

In an ambulatory setting, the Mini Nutritional Assessment (MNA) can be utilized to identify malnutrition (Table 3). The MNA is a simple assessment that does not require a nutrition specialist. The MNA has been studied in a predominantly elderly population and has been validated in several chronic medical conditions, such as Parkinson’s disease, COPD, and malignancy.^{5,6,48} The full MNA evaluates factors such as

mobility, amount of nutrition intake, weight loss, and social interactions, including stress level and independent living.⁴⁸ A validated short form (MNA-SF) focuses on the following six factors: food intake, weight loss, mobility, BMI and presence of psycho-social stress, dementia, and depression.⁴⁹ Calf circumference can be substituted in place of BMI, with a measurement of <33 cm suggesting malnutrition.

Physical examination and body composition measurements

Patients identified at risk for malnutrition should have their height and weight measured by clinicians. Clinician's height and weight measurements have been shown to be more accurate than self-reported values.⁵⁰ BMI can be calculated to identify underweight or overweight (or obese), based on the World Health Organization and the National Institutes of Health values: underweight (BMI <18.49 kg/m²), healthy weight (BMI 18.5–24.9 kg/m²), overweight (BMI 25.0–29.9 kg/m²), and obese (BMI ≥30 kg/m²). Waist circumference (WC) measurement further risk stratifies patients with a BMI of between 25 and 35 kg/m². WC values >102 cm in men and >88 cm in women increase the risk for obesity-related comorbidities.⁵¹ Functional assessments can objectively identify the current level of physical functioning and the longitudinal impact of nutrition support after subsequent visits. Functional assessments include a stair climbing test, a 30-second chair stand, a 4×10 m fast-paced walk, and a 6-minute walk test.⁵²

Classic physical examination findings to identify malnutrition may not be readily apparent in obesity. BMI does not identify the different phenotypes of obesity, such as sarcopenic obesity.⁵³ Over the past decade, there has been an increased use of imaging to better define the body composition, sarcopenia, and potential malnutrition. Dual-energy X-ray absorptiometry (DXA) and computed tomography (CT) have been used in research settings. DXA provides information of the regional breakdown of soft tissue compartments, such as adipose tissue and fat-free mass (FFM).⁵⁴ Similarly, CT-derived segmentation of the L3 psoas muscle can identify and differentiate muscle and adipose tissue.⁵⁵ Software-validated regression equations estimate whole body adipose tissue and muscle mass, which have been correlated to ICU, cancer-related, and liver disease outcomes.⁵⁵ Bioelectrical impedance analysis (BIA) is a method that has become readily available to measure the body composition, and newer multi-frequency BIA correlates well with DXA measurements.^{54,56} As opposed to DXA and CT, the benefits of BIA include the absence of radiation exposure, portability, and ease of use.

How to provide tube feeding

Protein content

Given the importance of lean body mass (LBM) preservation to delay sarcopenia as well as the association of amino acid availability and MPS rate discussed earlier, protein intake is one of the most important factors in providing EN in the elderly. In the health ABC study, those with the highest quintile of protein intake had a 43% reduction in the loss of lean body mass over 3 years, as compared with those with the lowest quintile of protein intake.⁵⁷ However, despite the benefits, the question of how much protein and how frequently it should be provided remains unsettled. The current recommended dietary allowance (RDA) for protein is 0.8 g/kg/day for all healthy individuals aged >18 years,⁵⁸ whereas the World Health Organization recommends 0.66 g/kg/day (Table 5).⁵⁹ Despite these recommendations, studies have revealed that >10% of community dwelling and 35% of institutionalized elderly reported protein intake below the daily minimum requirements.⁶⁰ Experts have argued that part of the issue with suboptimal protein intake is a misinterpretation of the definition of RDA, which was established by the Institute of Medicine based on short-duration nitrogen balance studies in young adults estimating the minimum protein intake required to prevent the progressive loss of lean body mass.^{58,61} The RDA does not equal optimal protein intake, which can differ significantly with aging. Additionally, given anabolic resistance, the elderly individual without comorbidities may

Table 5 Recommendations for optimal nutrition therapy in the elderly

| | |
|---|--|
| Protein content | |
| Provide 0.66–1.2 g/kg/day for healthy adults and 1.5–2.0 g/kg/day in critically ill | |
| Provide high-quality whey protein when feasible in preference to soy and casein | |
| Balance provision of 25–30 g with each meal | |
| Calories | |
| Provide 25–30 kcal/kg/day | |
| Obese subjects provide | |
| 11–14 kcal/kg ABW/day for BMI 30–50 | |
| 22–25 kcal/kg IBW/day for BMI >50 | |
| Formula selection | |
| Standard polymeric formula | |
| Immune-modulating formula (with arginine and fish oil) in postoperative surgical ICU patients | |
| Route | |
| Enteral preferred over parenteral | |
| Initiate EN with gastric feeding | |
| Reserve SB feeding for patient intolerant of gastric feeding or high risk for aspiration | |

Abbreviations: ABW, actual body weight; BMI, body mass index; EN, enteral nutrition; IBW, ideal body weight; ICU, intensive care unit; SB, small bowel.

have a different optimal protein requirement than someone of similar age with significant comorbidities and frailty.

In the healthy population, there is a dose-dependent and saturable stimulatory effect of EAAs. Non-EAAs do not have a significant role in the stimulatory effect.^{22,62,63} Cuthbertson et al²² reported that the ingestion of 2.5, 5, or 10 g of essential AA increased MPS in a dose-dependent manner in healthy elderly men, although less so than their younger counterparts. Doses 20 and 40 g failed to increase MPS beyond the 10 g dose. Similarly, the ingestion of 113 g of 90% lean ground beef containing ~30 g of protein and 10 g of essential AA by young and healthy elderly men and women lead to a 50% increase in MPS above fasting baseline.⁶⁴ In a subsequent experiment, the ingestion of 340 g of lean beef (90 g of protein and 30 g of essential AA) did not increase MPS, suggesting that 10 g of essential AA may be sufficient for maximal MPS.⁶⁵ Whey protein at dose 35 g produced higher MPS in healthy elderly men compared to 10 or 20 g whey.⁶⁶

In addition to quantity, the quality, source, and timing of protein consumption are important. Although whey, soy, and casein are defined as sources of high-quality proteins, differences in their digestion kinetics lead to differing MPS rates. Whey protein, which tends to be digested and absorbed faster and has a higher leucine concentration, leads to higher MPS when compared with casein hydrolysate and casein.⁶⁷ Whey protein superiority in inducing MPS was confirmed in a study where ingestion of whey protein after unilateral leg resistance exercise produced 122% greater MPS, as compared with casein.⁶⁸ Surprisingly, whey protein also leads to a 31% greater MPS than soy, despite the fact that both soy and whey are acid soluble, which facilitates rapid digestion.⁶⁸ In elderly men, 20 and 40 g of soy protein produced reduced MPS, as compared with whey protein during both resting and postexercise conditions.⁶⁹

The Western diet is such that three times more protein is consumed for dinner than for breakfast.^{60,70} In noncritically ill patients, pulse-dose protein provided multiple times per day yielded better total body protein synthesis, as compared with continuous feeding.^{61,71} Mamerow et al,⁷⁰ using a cross-over design, examined the impact of even (~30 g with each meal) versus uneven (~10 g with breakfast, 15 g with lunch, and 65 g with dinner) protein distribution on MPS in healthy adults and found that even distribution was associated with a 25% increase in MPS, as compared with uneven distribution. All in all, the data support the consumption of 25–30 g of high-quality protein containing ~10 g of essential AA at each meal for maximal MPS stimulation. Thus, many experts have recommended that ~0.4 g/kg/meal for a total of 1.2 g/kg/day may be the optimal protein target in elderly adults.¹⁹

Protein requirements in the ICU

The sine qua non of critical illness is proteolysis. Inflammation leads to early and rapid mobilization of muscle AA for hepatic gluconeogenesis and reprioritization. Worse inflammation increases anabolic resistance, and when coupled with immobilization and existing muscle disuse, muscle loss ensues. Consequences of loss of LBM include poor wound healing, increased duration of mechanical ventilation, propensity for nosocomial infections, reduced strength, and impaired quality of life. Therefore, preserving LBM is paramount in critically ill patients.^{11,72} In one ultrasound-based study, rectus femoris muscle loss increased to 12.5% by ICU day 7 and 17.7% by day 10.⁷² Disuse in the setting of immobilization can partially explain the reduction in MPS. In one study of healthy adults, 5 days of immobilization produced a 3.5% reduction in quadriceps muscle cross-sectional area, a 1.4% reduction in mass, and a 9% reduction in strength.⁷³ Similarly, disuse and inflammation with and the inability of insulin to reduce proteolysis contributed to increased MPB in critically ill elderly patients.^{74,75}

Protein provision and weight-bearing exercises may blunt muscle loss and lead to improvements in clinical outcomes. The optimal dose of protein in critically ill patients is unknown.⁷⁶ The Society of Critical Care Medicine (SCCM) and ASPEN recommend EN to be initiated within 24–48 hours in the critically ill patient who is unable to maintain volitional oral intake.⁷⁷ If the patient is deemed to be at high nutritional risk (NRS-2002 ≥ 5 or modified NUTRIC score ≥ 5), efforts should be made to provide >80% of goal within 48–72 hours. The European Society for Parenteral and Enteral Nutrition (ESPEN) has also recommended initiating EN in all patients who are not expected to resume oral intake within 3 days.⁷⁸ Protein is recommended between 1.2 and 2.0 g/kg of actual body weight per day in the critically ill and higher in burn and multitrauma patients (Table 5).⁷⁷ The basis for the protein dose recommendation includes a number of studies with nitrogen balance as the outcome.⁷⁹ As an example, Ishibashi et al⁸⁰ tested three protein intake levels (1.1, 1.5, and 1.9 g/kg of FFM) and found that a median protein intake of 1.5 g/kg/FFM or 1.2 g/kg of actual body weight was associated with the lowest body protein loss. Similarly, multiple observational studies have suggested that a protein target of >1.2 g/kg of body weight was associated with lower mortality, even when independent of caloric goal.^{76,81–83}

Protein requirements under special circumstances

Protein requirements have been studied in the elderly with special circumstances. In the obese, protein targets shift

from being based on actual body weight to either ideal body weight (IBW) or FFM. Typically, an approach of hypocaloric feedings in the noncritically ill with protein prescriptions ranging between 1.5 g/kg IBW/day and 2.2 g/kg IBW/day has produced nitrogen balance equilibrium or positive nitrogen balance.⁸⁴ Weijs and Wolfe⁸⁵ explored protein requirements in older obese subjects during weight loss and found that protein intake >1.9 g/kg FFM was required for muscle accretion. In a trial between older and younger obese critically ill patients, a hypocaloric and high protein nutrition supplementation (protein >2.0 g/kg IBW/day) resulted in a similar negative nitrogen balance between older and younger patients.⁸⁶

Similar to obese elderly patients, those with renal or liver insufficiency require special consideration when calculating protein requirements. A low protein diet ranging 0.6–0.8 g/kg/day is recommended for non-nephrotic chronic kidney disease patients (Table 5).⁸⁷ In patients on renal replacement therapy, the optimal protein range may be 1.0–1.3 g/kg/day in noncritically ill and 1.5–2.5 g/kg/day in critically ill patients.^{88,89} The 2016 SCCM–ASPEN critical care guidelines suggest that protein is not restricted in critically ill patients with acute kidney injury requiring renal replacement.⁷⁷ Historically, protein restriction was recommended in liver disease with concern for the risk of increasing the nitrogen load.⁸⁸ However, acute liver failure and decompensated liver cirrhosis are being recognized as a heightened catabolic state leading to proteolysis. Liver cirrhosis is associated with pre-existing protein malnutrition and sarcopenia. The Veterans Affairs Cooperative Study in patients hospitalized for alcoholic hepatitis revealed that positive nitrogen balance was not achieved until patients were consuming ~1.2 g/kg/day of protein.⁹⁰ Similarly, a European multicenter trial revealed an improved 6-month survival in those receiving >77.6 g/day of protein.^{91,92} The 2016 SCCM–ASPEN guidelines suggest that protein requirements for patients with hepatic failure are determined in the same manner as those for the general ICU patient. The guideline recommends using dry weight for protein dose calculation in patients with ascites and/or fluid overload.⁷⁷ ESPEN guidelines recommend 0.8–1.2 g/kg/day in acute or subacute liver failure and 1.2–1.5 g/kg/day in liver cirrhosis.⁹³

Calories

Energy expenditure decreases with aging on the order of 150 kcal per decade and correlates with a decrease in FFM.^{94,95} Energy requirements may be either calculated through simple weight-based estimations (~25–30 kcal/kg/day) and predictive equations (eg, Harris–Benedict equation) or measured

via indirect calorimetry (Table 5).^{77,78,96} Equation-based derivation of resting energy expenditure has been shown to be within 10% of values obtained with indirect calorimetry.^{97,98} At the extremes of BMI (<18 and >40), the accuracy of predictive equations decreases.^{77,99} For most clinical scenarios, the availability and ease of use of predictive equations make them optimal for initial energy expenditure calculations with subsequent adjustments being made to the caloric content based on desired weight trajectory.

In obese patients, hypocaloric high-protein EN is typically recommended with an overall caloric goal of 22–25 kcal/kg IBW/day.⁸⁴ Although the results have been heterogeneous, some trials comparing hypocaloric (~18–25 kcal/kg IBW/day) to eucaloric (30–42 kcal/kg IBW/day) nutrition supports have shown benefit with hypocaloric in terms of decreased length of ICU stay and a trend toward decreased ventilator and hospital days.^{84,86,100} The 2016 SCCM–ASPEN guideline recommends that EN caloric dose should not exceed 65%–70% of target energy needs based on indirect calorimetry or 11–14 kcal/kg of actual body weight per day for patients with BMI 30–50 kg/m² and 22–25 kcal/kg IBW/day for patients with BMI >50 kg/m².⁷⁷

Formula selection and specialty formulas

For the majority of critically and noncritically ill patients, a standard polymeric formula can be utilized when initiating EN (Table 6). A number of specialty formulas, including diabetes specific, branched chain amino acids (BCAAs) for liver disease, and immune-modulating formulas, have been studied with heterogeneous results (Table 6). As an example, BCAAs have been studied extensively in liver disease, given their numerous theoretical benefits including providing an alternative pathway for ammonia detoxification through synthesis of glutamine from glutamate and ammonia in muscle, leucine-mediated activation of mTOR pathway leading to improved MPS, leucine-induced stimulation of hepatic growth factor, BCAA prevention of tissue triglyceride accumulation, and improvement in neutrophil phagocytic function.^{88,101} Unfortunately, despite these theoretical benefits, clinical trial results have not been promising, leading major societies to recommend the selective use of specialized enteral formulas containing BCAAs in critically ill patients with liver disease.^{77,88,93,102} As an example, ESPEN guidelines recommend providing the standard solution in patients with mild encephalopathy and a liver-adapted EN containing increased amounts of BCAA and decreased aromatic amino acids, methionine, and tryptophan in those with more severe encephalopathy (grades III–IV).⁹³

Table 6 Macronutrient content of available formulas

| Formula type | kcal/mL | Protein (g/L) | Protein source | Fat (g/L) | Fat source | Carbohydrate (g/L) | Carbohydrate source | Examples of formulas |
|-----------------------------|---------|---------------|--|-----------|---|--------------------|--|--|
| Standard polymeric | 1–1.2 | 52–54 | Soy protein isolate and sodium and calcium caseinates | 35–40 | Canola oil, MCT oil, soy lecithin, or safflower oil | 144–164 | Corn syrup, maltodextrin, and dextrose | Nutren 1.0, Osmolite 1.0, Isosource HN, Osmolite 1.2, Fibersource HN, Jevity 1.2 |
| Calorically dense | 1.5–2.0 | 63–84 | Soy protein isolate and sodium and calcium caseinates | 49–92 | Canola oil, MCT oil, soy lecithin, and safflower oil | 176–219 | Corn syrup, maltodextrin, and dextrose | Nutren 1.5, Osmolite 1.5, Isosource 1.5, Jevity 1.5, Nutren 2.0, TwoCal HN |
| High protein | 1 | 63–64 | Soy protein isolate and sodium and calcium caseinates | 26–34 | Canola oil, MCT oil, and soy lecithin | 112–138 | Corn syrup, maltodextrin, and dextrose | Replete, replete with fiber, promote, and promote with fiber |
| Renal (dialysis) | 2 | 81–91 | Sodium, calcium, and magnesium caseinates, soy protein isolate, and milk protein isolate | 96–100 | Canola oil, soy lecithin, and safflower oil | 161–183 | Corn syrup, sugar (sucrose), and maltodextrin | NovaSource Renal, Nepro with Carb Steady |
| Liver | 1.5 | 40 | L-Amino acids and whey protein concentrate | 21 | MCT oil, canola oil, corn oil, and soy lecithin | 290 | Maltodextrin and modified cornstarch | NutriHep |
| Semielemental | 1–1.2 | 40–76 | Enzymatically hydrolyzed whey protein (peptides) and hydrolyzed sodium caseinate | 38–57 | MCT oil, soybean oil, and soy lecithin | 111–130 | Maltodextrin, cornstarch, sugar (sucrose), and sucralose | Peptamen, Vital 1.0, Peptamen AF, Vital AF 1.2, Peptamen with Pre-Bio |
| Semielemental calorie dense | 1.5 | 68 | Enzymatically hydrolyzed whey protein | 56–57 | MCT oil, soybean oil, soy lecithin, and interesterfied canola oil | 187–188 | Maltodextrin, cornstarch, sugar (sucrose), and sucralose | Peptamen 1.5, Peptamen 1.5 with Prebio, Vital Peptide 1.5 |
| Elemental | 1 | 21–50 | Free amino acids | 2–12 | MCT oil, soybean oil, and safflower oil | 176–226 | Maltodextrin, modified cornstarch, and dextrose | Vivonex RTF, Tolorex |

Abbreviations: MCT, medium chain triglycerides; HN, high nitrogen; RTF, ready to feed; AF, advance formulation.

Although immune-modulating formulas (typically containing arginine, eicosapentaenoic acid [EPA], docosahexaenoic acid [DHA], glutamine, and nucleic acid) have shown limited benefits over standard formulas in the medical ICU, warranting a recommendation against routine use in ICU patients. Immuno-nutrition may be of benefit in postoperative surgical ICU patients.⁷⁷ Meta-analyses have demonstrated immune-modifying formulas containing arginine- and fish oil-reduced infection, hospital length of stay, and postoperative complications in surgical ICU patients, when compared with standard formulas.^{103–107} Based on these studies, it appears that maximal benefit is achieved when these formulas are provided pre-, peri-, and postoperatively in both well-nourished and malnourished patients.⁷⁷

Route of EN

Another important consideration for providing EN is the method of EN delivery. In critically ill patients, two common

strategies for providing EN are gastric and postpyloric (eg, jejunal) feeding. Randomized control trials (RCTs) have compared the effect of gastric versus postpyloric tubes on various outcomes and showed mixed results. Neumann and DeLegge,¹⁰⁸ in an RCT of 60 medical ICU patients undergoing bedside placement of enteral tube, showed that patients who received EN delivered in the stomach received nutrition sooner and with fewer attempts at feeding tube placement and reached goal rate sooner, as compared with those who received a postpyloric tube. Montecalvo et al¹⁰⁹ randomized 38 patients to nasogastric (NG) versus endoscopically placed nasojejunal (NJ) and showed that the NJ group received a significantly higher percentage of their daily goal calories. They also reported two nosocomial pneumonias in the NG group and none in the NJ group. Kortbeek et al¹¹⁰ randomized 80 mechanically ventilated patients to NG or nasoduodenal feedings and demonstrated a higher pneumonia rate in the NG group. In one of the largest RCTs of NG compared to NJ feeding, Davies et al¹¹¹ found no

differences in calories delivered or clinical outcomes such as pneumonia, aspiration, diarrhea, and mortality. Several meta-analyses have shown either no difference between gastric and small bowel (SB) feeding or a reduction in pneumonia alone with SB feeding (with no difference in any other outcome parameter including duration of mechanical ventilation and hospital LOS). Based on the data available, major guidelines recommend initiating EN in the stomach and then progressing to postpyloric feeds if there is intolerance or the patient is deemed a high risk for aspiration.^{77,78}

Similarly, for the noncritically ill patient, EN is usually initiated in the stomach. A paucity of data exists regarding the method of EN delivery in the elderly. In elderly patients who require long-term EN, percutaneous endoscopy gastrostomy (PEG) has been found to be superior to NG tube feeding.¹¹² Ciocon et al¹¹³ prospectively evaluated 70 patients aged 65–95 years who were receiving EN through NG, NJ, gastrostomy, or jejunostomy tube. Although the duration of tube feeding ranged from 1 month to 8 years, they were able to follow 56 patients for 11 months. Indications for EN were refusal to swallow due to cognitive dysfunction, such as dementia (50%), dysphagia without obstruction (47%), and esophageal obstruction (3%). Patients with nasoenteric tubes (NJ and NG) experienced agitation, high rates of self-extubation (~67%), aspiration pneumonia, tube kinking, and tube clogging, as compared with percutaneous tube.

Conclusion

Malnutrition and sarcopenia are highly prevalent in the elderly and lead to significant morbidity and mortality. In addition to physical activity, adequate nutrition support, especially high-quality protein consumption, is key to mitigate the changes that occur with MPS and MPB due to age and the disease state. A number of risk stratification calculators are available for providers to help identify patients at risk in the ICU, hospital, and outpatient settings. Additionally, tools such as BIA are becoming more readily available and can provide a more rigorous assessment of LBM, allowing longitudinal assessment. More data are also forthcoming to indicate that perhaps the previous recommendations for protein intake are insufficient to meet the needs of the elderly population, given the associated anabolic resistance. As such, experts are recommending higher amounts of high-quality protein on the order of 1.2 g/kg provided in an intermittent and balanced manner for maximal MPS if possible. For the critically ill, even higher amounts of protein may be necessary to prevent further debility. Large multicenter prospective trials are needed to help further delineate adequate nutrition and protein needs for this increasingly prevalent cohort.

Disclosure

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