

Neurologic Impairment

Barbara Magnuson Woodward, PharmD, CNSC, Douglas R. Oyler, PharmD, BCCCP, Kathryn Ruf, PharmD, BCPS, Natalia Bailey, MS, RD, CD, and Jimmi Hatton Kolpek, PharmD, FCCP, FCCM, FNAP

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Objectives

Discuss energy and protein assessment in patients with acute neurologic injury, such as traumatic brain injury (TBI), spinal cord injury (SCI), and stroke.

Explain current clinical approaches to glucose, sodium, and fluid resuscitation and the use of immunonutrition in acute neurologic injury.

Describe common nutrition-related challenges inherent in the acute rehabilitation of the neurologically injured patient.

Understand energy and protein assessment and other nutrition-related challenges in patients with chronic neurologic diseases.

Test Your Knowledge Questions

1. Which of the following is most strongly correlated with improved mortality in TBI?
 - A. Strict avoidance of parenteral nutrition (PN)
 - B. Early initiation of nutrition
 - C. High protein content in nutrition formula
 - D. Supplementation of vitamins C and E

2. Which of the following commonly used medications in TBI is not associated with a reduction in measured energy expenditure?
 - A. Propranolol
 - B. Mannitol
 - C. Pentobarbital
 - D. Rocuronium

3. Metabolic changes following SCIs depend on the level of cord injury and the extent of injuries. Which of the following statements is true?
- A. The energy expenditure following SCI is approximately 48% higher than that following TBI.
 - B. To accurately assess the energy requirements for a patient with SCI, multiply the resting energy expenditure (calculated with the Harris-Benedict equation) by an injury factor of 1.6 and then again by an activity factor of 1.2.
 - C. A modified body mass index (BMI) scale has been proposed for individuals with SCI, with healthy normal categorized as BMI 18 to 22.
 - D. Patients with chronic SCI require approximately 30 to 33 kcal/kg/d depending on their physical activity.
4. Which of the following statements regarding a subarachnoid hemorrhage (SAH) is false?
- A. High doses of folic acid should be administered to reduce the likelihood of a second hemorrhagic stroke.
 - B. Energy expenditure is higher for patients with SAH than for those with ischemic stroke.
 - C. Concentrated enteral nutrition (EN) may be necessary if fluid intake is restricted to minimize cerebral edema.
 - D. Bedside or formal swallow studies should be performed to confirm that the patient does not have dysphagia before an oral diet is initiated.

Test Your Knowledge Answers

- 1. The correct answer is B. Of the choices, only early initiation of nutrition has been associated with improved outcomes. EN is preferred in patients with TBI because of the general benefits associated with it, but available evidence does not suggest a strong correlation between PN provision and worsened outcome in TBI (answer A is incorrect). Protein needs are increased after trauma, but provision of high-protein nutrition is not directly correlated with outcomes in TBI (answer C is incorrect). While supplementation of antioxidants is likely beneficial for neurologic recovery after TBI, vitamin replacement has not changed mortality (answer D is incorrect).
- 2. The correct answer is B. Propranolol, pentobarbital, and all neuromuscular antagonists have been shown to reduce energy expenditure after administration (answers A, C, and D are incorrect). Mannitol does not affect energy expenditure.
- 3. The correct answer is C. Energy expenditure following SCI has been repeatedly reported to be almost 48% lower than following TBI. Most patients with SCI will expend 5% to 15% more energy than estimated with the Harris-Benedict equation, and, therefore, Harris-Benedict equation should not be multiplied by extreme injury or activity factors. In the chronic phase, patients with SCI are at risk for obesity and related disorders such as diabetes and cardiovascular disease.

Generally, these patients require approximately 20 to 23 kcal/kg/d, depending on their physical activity. A modified proposed BMI scale suggests a normal healthy BMI be 18 to 22.

4. The correct answer is A. The VITATOPS study concluded that daily folic acid and vitamin B6 and B12 supplements did not reduce the recurrence of an ischemic stroke.¹ Recent studies show the SAH is likely more hypermetabolic than the ischemic stroke. Concentrated enteral formulas may be indicated if the patient has a free water or total fluid restriction to minimize cerebral edema. The Joint Commission dropped mandatory dysphagia screening from their core measures as of January 2010, but such screening remains part of many stroke quality programs to ensure that no dysphagia is present prior to advancing an oral diet.²

Introduction

The central nervous system (CNS) acts as a regulator of nutrient intake. It does so via internal signaling mechanisms that maintain homeostasis of blood glucose and electrolytes and by triggering awareness of hunger and thirst. In CNS injury, these normal physiological functions become disrupted. The severity of this disruption depends on the acuity and magnitude of the brain insult. Acute TBI and stroke generate immediate consequences on nutrition intake and metabolic parameters. Chronic, degenerative diseases of the brain can also cause significant nutrition complications, which gradually become evident as the disease progresses. Residual neurologic function often changes over time, generating different nutrition concerns depending on the stage of CNS recovery.

Numerous factors are pertinent when evaluating nutrition support in a neurologically impaired patient. Nutrition assessment provides the basis for nutrition interventions, in both the acute care and rehabilitation settings. TBI and SCI often affect young, healthy men; in contrast, malnutrition and concomitant diseases are more common in patients with acute stroke or Parkinson's disease. Independent of the initial diagnosis, the extent of neurologic recovery following CNS injury is a common, primary factor to consider when determining nutrition recommendations. Nutrition support is no longer considered adjunctive in the critical care population; rather, it is understood to be therapy to attenuate the metabolic response to stress, prevent metabolic oxidative stress, and modulate the immune response.³ Nutrition therapy continues to be a vital component in the acute and long-term rehabilitation populations for continued healing and further prevention of malnutrition.

This chapter reviews the nutrition support therapies for a variety of neurologic impairments, beginning with the acute critical phases of TBI, SCI, and stroke. Equally important to the initial therapies provided in the intensive care unit (ICU) are the therapies provided during the acute rehabilitation phase of injury recovery. This chapter also addresses distinctive nutrition challenges associated with several chronic neurologic disease states, including amyotrophic lateral sclerosis (ALS), epilepsy, and Parkinson's disease.

Nutrition in Acute Traumatic Brain Injury

Nutrition Requirements

TBI is a heterogeneous injury that drastically varies in etiology, clinical presentation, severity, and pathophysiology. In general, the acute phase of TBI can be categorized as a hypermetabolic, catabolic one that is proportional to the severity of injury.⁴ The subsequent rapid depletion of muscle mass and immunosuppression have been associated with increased morbidity,^{5,6} and early provision of nutrition has been proposed as a preventive measure.⁷ At present, the Brain Trauma Foundation (BTF) guidelines provide no level 1 recommendations regarding nutrition in TBI.⁸

The primary benefits of adequate nutrition support in the trauma patient are threefold: prevention of protein malnutrition, modulation of the immune response, and preservation of gastrointestinal (GI) structure and function.⁹ If exogenous energy is not supplied to the acutely injured patient with a severe stress response, the requirements are ultimately met through skeletal muscle proteolysis followed by breakdown of visceral and circulating proteins, which has a direct effect on immune function.¹⁰ Specific types of amino acid supplementation (discussed under “Immunonutrition,” later in this section) may have a direct role in ameliorating critical illness–mediated immunosuppression.¹¹ Administration of early EN has been shown to help prevent GI dysfunction that may occur as a result of neuroendocrine reflexes and ischemia/reperfusion injuries as well as multiple concomitant interventions in critical care (eg, abdominal surgery and medication therapy with some types of H₂-antagonists and opioids).¹²

Depending on the severity of TBI, concomitant injuries, and medical management, measured energy expenditure can vary from 87% to 200% of the energy expenditure estimated by using the Harris-Benedict equation (the predictive equation most studied in the TBI literature).¹³ Use of neuromuscular blocking agents (NMBAs), nonselective beta-blockers, morphine, and barbiturates is associated with reductions in measured energy expenditure (discussed under “Pharmacological Therapies,” later in this section).^{14–18} Where available, use of indirect calorimetry (IC) to estimate energy needs is strongly encouraged.³ If IC is unavailable or impractical to use, estimating energy requirements to be 140% of what the Harris-Benedict equation predicts is recommended by the BTF, American Association of Neurological Surgeons, and Congress of Neurological Surgeons.¹⁹ Protein requirements are in the range of 1.3 to 2.5 g/kg/d.^{20,21} See Chapter 2 for a broader discussion of IC and predictive energy equations. See Chapter 6 for additional information on protein.

Finally, multiple alterations occur in the productions of hormonal and inflammatory mediators, including growth hormone, adrenocorticotropin-releasing hormone, cortisol, prolactin, glucagon, vasopressin, and catecholamines.²² Lower concentrations of zinc, magnesium, and insulin-like growth factor 1 (IGF-1) may also worsen outcomes after TBI. Supplementation with zinc and IGF-1 has been shown to improve some outcomes after TBI.^{23,24} Table 22-1 highlights major metabolic alterations after TBI.^{23,25–27}

TABLE 22-1 Metabolic Alterations After Traumatic Brain Injury

Diminished Concentrations in CNS Injury	Elevated Concentrations in CNS Injury
Albumin	Alpha-1 acid glycoprotein
Insulin-like growth factor-1	C-reactive protein
Iron	Ceruloplasmin
Prealbumin	Interleukin-1
Thyroxine	Interleukin-6
Thyroid-stimulating hormone	Vasopressin (in SIAD)
Transferrin	Cortisol (acute injury)
Vasopressin (in diabetes insipidus)	Growth hormone (acute injury)
Zinc	
Cortisol (chronic injury)	
Growth hormone (chronic injury)	

CNS, central nervous system; SIAD, syndrome of inappropriate antidiuresis.

Source: Data are from references 23 and 25–27.

Role of Nutrition Support

Outcomes for patients with TBI are likely better correlated to the timing of nutrition than the route of nutrition. A recent Cochrane review analyzed 11 prospective trials involving patients with TBI, including 7 studies that addressed the timing of nutrition support (total N = 284 patients). In those 7 trials, provision of early (within 24 to 72 hours of injury) nutrition support was associated with a trend toward reduced mortality when compared with late (within 3 to 5 days) nutrition support (risk ratio [RR] = 0.67; 95% confidence interval [CI], 0.41–1.07).²⁸

The importance of early nutrition is further illustrated in a recent retrospective database review conducted by the BTF, wherein patients who received no nutrition within 5 and 7 days after isolated severe TBI with or without polytrauma had a 2- and 4-fold increased likelihood of death, respectively, when compared with patients who received nutrition within each time frame.²⁹ Furthermore, the risk of mortality increased by 30% to 40% with each 10 kcal/kg decrease in the amount of nutrition provided, even after the analysts controlled for other predictors of mortality.

A meta-analysis by Wang and colleagues evaluated EN vs PN in patients sustaining TBI and showed no significant difference in outcomes.³⁰ In fact, PN was associated with nonsignificant reductions in mortality (RR = 0.61; 95% CI, 0.34–1.09), poor outcome (RR = 0.73; 95% CI, 0.51–1.04), and infectious complications (RR = 0.89; 95% CI, 0.66–1.22). Of note, most mortality (28/41) and poor outcome events (49/63) occurred in studies that randomly assigned patients to early PN vs late EN, and infectious complications data were strongly driven by pneumonia rates.³⁰

A recent retrospective study found an increased risk of pneumonia in 90 patients with severe TBI (Glasgow Coma Scale less than 8) who were fed enterally; notably, 70% of the patients in this study received EN via an orogastric or nasogastric tube.³¹ However, in light of the well-known benefits of EN when compared with PN, clinicians are urged to start EN as soon as possible following TBI to maximize its benefits. Given the poor outcomes associated with delayed nutrition in the TBI population, a low threshold for using PN if a patient does not tolerate EN is advised.

Special Considerations

Sodium

Hyponatremia (serum sodium less than 135 mEq/L) is common in patients in neurosurgical ICUs and contributes to worsening cerebral edema, intracranial pressure elevations, and death from herniation.³² A serum sodium concentration of less than 130 mEq/L has been associated with a 60-fold increase in case fatality rate.³³ TBI is a common cause of the syndrome of inappropriate antidiuresis (SIAD), which results in euvoletic hyponatremia. Because of the euvolectia and normal urine volume, SIAD is often difficult to detect before clinical symptoms manifest unless the patient's serum sodium concentration is monitored. Because SIAD is typically transient, fluid restriction is the primary method of treatment; however, caution should be used in the acute phase of neurologic insult because volume restriction may be inappropriate.³⁴ Pharmacological treatment with demeclocycline, sodium supplementation, or vasopressin antagonists should only be used in refractory cases.

Cerebral salt wasting (CSW) is a rare hypovolemic hyponatremia characterized by increased natriuresis; like SIAD, CSW is usually transient after TBI.³⁵ CSW is a diagnosis of exclusion and should only be considered in hypovolemic patients when another cause of natriuresis is not identified. CSW should be managed with intravenous (IV) sodium supplementation. In both SIAD and CSW, hyponatremia should be corrected no faster than 10 to 12 mEq/L/d to avoid central pontine myelinolysis.³⁶

Diabetes insipidus is a hypernatremic state characterized by a deficiency in vasopressin (neurogenic), lack of response to vasopressin (nephrogenic), or accelerated degradation of vasopressin (gestational).³⁷ Neurogenic diabetes insipidus is the most common type; damage to the hypothalamus or posterior pituitary, usually as a result of rotational forces sustained in motor vehicle collisions, reduces central vasopressin production leading to neurogenic diabetes insipidus after TBI.³⁸ Supplementation of salt-free water and replacement of vasopressin or analogues can reduce serum sodium to normal levels. As with hyponatremia, hypernatremia should be corrected no faster than 10 to 12 mEq/L/d to avoid worsening of cerebral edema.

Hyperglycemia

Hyperglycemia following TBI has been linked to poor neurologic outcomes,³⁹ but the role of glucose in secondary injury has not been elucidated. Hyperglycemia may induce lactic acidosis as well as endothelial dysfunction and cerebrovascular changes during ischemia and reperfusion. Additionally, hyperglycemia enhances neutrophil transmigration across the blood-brain barrier and, along with tumor necrosis factor, activates production of interleukin-8.⁴⁰ The impact of hyperglycemia on its own,

weighed against the risk of inadequate provision of nutrition, has not been evaluated. At present, the maintenance of serum glucose in patients with TBI is expected to be similar to maintenance for other critically ill populations.⁴¹ (Refer to Chapter 34 for more information on managing hyperglycemia in critical illness.)

Pharmacological Therapies

Pharmacological therapies used as part of the care of a patient with TBI can have important implications for nutrition support therapy. Table 22-2 provides a list of medications that may affect nutrition support or subsequent monitoring.^{14,18,42,43} Many medications may cause electrolyte abnormalities, and several others can reduce energy expenditure to varying degrees.

TABLE 22-2 Medication Considerations in Traumatic Brain Injury

Medication	Nutrition Implications
Barbiturates	May reduce energy requirements. Combine with bowel regimen.
Carbamazepine	Avoid combining suspension with water or other medication diluents (forms rubbery precipitate). Monitor for hyponatremia.
Corticosteroids	Monitor for hyperglycemia.
Demeclocycline	Avoid combination with divalent cations (eg, magnesium, calcium) or EN.
Mannitol	Monitor for hypokalemia, hypomagnesemia, hypovolemia.
NMBAs (eg, rocuronium, cisatracurium)	May reduce energy requirements.
Phenytoin	Caution combining suspension with EN (diminished/delayed absorption. Hold EN at least 1–2 hours before and after administration).
Propofol	10% lipid emulsion provides 1.1 kcal/mL.
Propranolol	May reduce energy requirements.

EN, enteral nutrition; NMBA, neuromuscular blocking agent.

Source: Data are from references 14, 18, 42, and 43.

Based on numerous recent studies,^{44–46} propranolol therapy in the acute phase of TBI may soon be used more frequently. Propranolol administration has been shown to reduce measured energy expenditure by 5% to 18%, likely related to a reduction in response to circulating catecholamines.^{14,15} Morphine, which may be used for analgesia or to mediate symptoms of paroxysmal sympathetic hyperactivity (PSH), can reduce energy expenditure by up to 8%.¹⁶ For management of PSH, morphine and propranolol may be used concomitantly,⁴⁷ and it is plausible that their effects on energy expenditure are additive.

Pentobarbital may be used to reduce intracranial pressure after TBI, primarily by reducing cerebral blood volume and cerebral metabolism.⁴² Dempsey and colleagues found that induction of pharmacological coma using pentobarbital reduced energy expenditure by up to 32% compared with no

barbiturate therapy ($86\% \pm 28\%$ vs $126\% \pm 36\%$ of predicted energy expenditure using Harris-Benedict equation; $P < 0.01$).¹⁷

NMBAs have also been used to reduce intracranial pressure after TBI and can affect energy requirements. In 18 patients with severe head injury receiving pancuronium, NMBA administration reduced energy expenditure to basal levels independent of morphine use, body temperature, and feeding.¹⁸ A smaller study of patients receiving midazolam and vecuronium or pancuronium showed a reduction of energy expenditure to levels below what the Harris-Benedict equation predicted, similar to energy expenditure levels seen with barbiturate therapy.⁴⁸

Immunonutrition

Immunonutrition is the supplementation of specific nutrients—mainly arginine, glutamine, ω -3 fatty acids, and antioxidants—with the intent of immunomodulation. Because immune function in critical illness is heterogeneous among patients and among patient groups,⁴⁹ broad conclusions about the safety or efficacy of various components of immunonutrition in critically ill patients should be avoided.

Arginine

L-arginine is required for regulation of cerebral blood flow, extracellular matrix remodeling, and energy production.⁵⁰ Low circulating levels of arginine have been postulated to be a critical component of the development of the persistent inflammation, immunosuppression, and catabolism syndrome after critical illness.¹¹ After severe TBI, plasma levels of arginine and metabolic byproducts (citrulline, ornithine, urea, proline, and 4-hydroxyproline) are significantly decreased; these alterations in plasma arginine and metabolites may contribute to secondary injury following TBI.⁵¹ Importantly, the decrease in plasma arginine seems to occur through a different mechanism than in other models of critical illness (eg, sepsis), where the L-arginine nitric oxide pathway seems to be hyperactive.⁵² (Refer to Chapter 23 for more information on sepsis.)

Despite an abundance of theoretical evidence, clinical research has not found that arginine supplementation in trauma and TBI improves outcomes. A recent systematic review of 8 studies enrolling 372 patients indicated that pharmaconutrition did not improve infection, hospital length of stay, or mortality outcomes.⁵³ Seven of these studies ($n = 300$ patients) included arginine as part of the nutrition formula.

Of theoretical concern is the ability of L-arginine to be converted to nitric oxide, which may react with reactive oxygen species to form peroxynitrite. However, this reaction is likely more related to levels of nitric oxide synthase as opposed to arginine supplementation.⁵⁴

Glutamine

Glutamine plays a central role in nitrogen transport and is fuel for the rapidly dividing cells of the gut and immune system.⁵⁵ Low plasma glutamine concentration at ICU admission is an independent risk factor for post-ICU mortality in critically ill patients.⁵⁶ The mechanism underlying this association with mortality is currently unknown.

Despite the association of low plasma glutamine concentration with poor outcomes, early provision of glutamine did not improve these outcomes in a large-scale study of critically ill patients.⁵⁷ However, in this study, only 2.5% of patients were admitted with trauma; given the heterogeneity of critically ill patients, extrapolation of these results to the TBI population should be done with extreme caution.

Theoretically, glutamine supplementation may increase cerebral glutamate concentration, which may act to worsen secondary injury through N-methyl-D-aspartate (NMDA) receptor agonism.²² The available evidence to date does not support this hypothesis. A recent study of 12 patients with severe TBI who were given IV glutamine supplementation showed an increase only in plasma and cerebrospinal fluid (CSF) concentrations of glutamine and alanine; CSF glutamate concentrations significantly decreased during and after glutamine infusions.⁵⁸ No signs of potential glutamate-mediated cerebral injury were noted.

ω-3 Fatty Acids

The human brain is 60% lipid by dry weight, and docosahexaenoic acid (DHA) comprises 50% of neuronal membrane phospholipids.⁵⁹ Because of its extreme flexibility, DHA is abundant in neuronal synapses. Additionally, both DHA and eicosapentaenoic acid (EPA) have the ability to transform into neuroprotective metabolites that protect against oxidative stress, tissue inflammation, and synaptic degradation.^{60,61} Following TBI, existing DHA and EPA are converted to neuroprotectins and resolvins, which upregulate antiapoptotic cascades and expression of receptor families involved in tissue repair,^{62,63} thereby improving neurologic outcomes in animal models or with preinjury supplementation.^{64–66} No clinical trial data regarding post-TBI ω-3 supplementation in humans are presently available.

Antioxidants

Lipid peroxidation biomarkers—such as thiobarbituric acid–reactive substances, protein carbonyls, and 8-iso-prostaglandin F_{2α}—are increased following TBI and have been correlated with clinical outcomes.⁶⁷ Oxidative stress following TBI may lead to excitotoxicity, mitochondrial dysfunction, apoptosis, autophagy, cerebral edema, and inflammation.⁶⁸ To attenuate this response, a number of antioxidant substances have been evaluated, including ω-3 fatty acids, ascorbic acid, and α-tocopherol.^{69,70}

Plasma ascorbic acid levels are suppressed following head trauma.⁷¹ Supplementation of ascorbic acid may protect neurons from NMDA-induced excitotoxicity and lipid peroxidation.⁷² Furthermore, ascorbic acid supplementation may be beneficial because ascorbic acid transport through the sodium-dependent vitamin C transporter may be altered in TBI, and the ability of cells to maintain high levels of intracellular ascorbic acid may be reduced.

α-Tocopherol is the major peroxy radical scavenger in lipid membranes.⁷³ Preinjury supplementation has been shown to be beneficial in rat models of TBI, and ascorbic acid supplementation may reduce α-tocopheroxyl to improve α-tocopherol levels.⁶⁹ In a study of 100 patients with severe TBI, supplementation of 400 IU of intramuscular vitamin E per day significantly improved mortality and Glasgow Outcomes Score at discharge compared with placebo.⁷⁰

At present, available information is insufficient to recommend specific dosing strategies of any pharmaconutrient to patients with TBI. Additionally, evidence is lacking regarding the clinical benefits of supplementation. However, given the significant amount of theoretical evidence supporting the use of pharmaconutrition in the trauma population, its use is recommended in patients with TBI,³ and exogenous supplementation of ω -3 fatty acids, ascorbic acid, and vitamin E should be considered as recommended in the 2016 American Society for Parenteral and Enteral Nutrition (ASPEN) and Society of Critical Care Medicine (SCCM) guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient.³ Practice Scenario 22-1 explores the use of pharmaconutrition and other aspects of an optimal nutrition support regimen for a patient with acute TBI.^{3,19,20}

Practice Scenario 22-1

Question: What is the optimal nutrition support regimen for a patient in the acute phase of a traumatic brain injury (TBI)?

Scenario: A 35-year-old woman was admitted with a severe TBI after a motor vehicle collision. She has multiple other orthopedic injuries, including a left femur fracture, right 3–7 rib fractures, and a right humerus fracture. Her presenting Glasgow Coma Score was 7T, and she has remained intubated because of her neurologic status. The nutrition support clinician is asked to evaluate the patient's current enteral nutrition (EN) regimen and recommend changes if necessary. The patient is receiving a 1.2 kcal/mL formula at a rate of 60 mL/h through a postpyloric small-bore feeding tube and is tolerating it well. The nutrition assessment notes:

- Height: 162.5 cm
- Weight: 62 kg
- Enteral formula: 1.2 kcal/mL, 54 g protein per liter, and 809 mL free water per liter administered at rate of 60 mL/h.
- Medications: Enteral administration of 100 mg phenytoin suspension every 8 hours, with enteral feeds held for 1 hour before and 1 hour after each dose; enteral administration of 100 mg docusate twice daily; 30 mg enoxaparin administered subcutaneously twice daily; enteral administration of 20 mg famotidine twice daily; and 10 mg propofol per mL lipid emulsion as a continuous infusion running at 25 mcg/kg/min.

Intervention: Tube feedings are changed to an immune-modulating formulation (1.5 kcal/mL, 94 g protein per liter, 770 mL free water per liter, an ω -6 to ω -3 fatty acid ratio of 1.4:1, 18.7 arginine per liter, and 8.1 g glutamine per liter) at a rate of 55 mL/h. The patient's phenytoin administration is changed to 150 mg twice daily so the EN will need to be held for only 4 hours per day. At a rate of 55 mL/h for 20 hours per day, her nutrition support will provide 1650 kcal and 103.4 g protein per day. Additionally, she will receive 245 kcal/d from propofol.

Answer: Because of the variability in energy expenditure associated with TBI and the patient's medication regimen, indirect calorimetry (IC) should be performed to determine energy requirements. If IC is not done, the patient's energy requirements may be roughly estimated to be 1921 kcal/d, 40% more than the Harris-Benedict equation would predict.¹⁹ Approximately 1.3 to 2.5 g protein per kg body weight should be given per day (80 to 155 g/d for this patient). Immunonutrition and medication therapy (eg, propofol, phenytoin) should be considered.

Rationale: This patient's predicted energy expenditure, as estimated by the Harris-Benedict equation, is 1372 kcal/d. Accounting for an approximate 40% increase in energy expenditure associated with TBI,¹⁹ she may require 1921 kcal/d (31 kcal/kg/d). However, given the wide variability in measured energy expenditure associated with TBI and the unknown effect of propofol administration on energy expenditure, IC is recommended to accurately determine the patient's energy requirements.

The energy from 25 mg propofol per day is calculated as follows:

$$\frac{25 \text{ mcg propofol}}{\text{kg} \times \text{min}} \times 62 \text{ kg} \times \frac{60 \text{ min}}{\text{h}} \times \frac{24 \text{ h}}{\text{d}} \times \frac{1 \text{ mg propofol}}{1000 \text{ mcg propofol}} \times \frac{1 \text{ mL propofol}}{10 \text{ mg propofol}} \times \frac{1.1 \text{ kcal}}{\text{mL propofol}} = 245 \text{ kcal}$$

Because phenytoin suspension requires separation from EN by 1 hour, each administered phenytoin dose results in 2 hours of nutrition missed. By changing phenytoin administration to twice daily, EN can be administered for 20 hours as opposed to 18. (Phenytoin suspension should not be given once daily because of the short half-life of the drug.)

Using a more energy-dense formula will reduce this patient's administered free water, which may prevent development of hyponatremia. Very energy-dense formulations (eg, 2 kcal/mL) may not provide adequate protein and typically require exogenous protein supplementation. Medication administration, specifically of powder packets, typically requires additional free water to administer, which may negate the benefit of an energy-dense formulation. For that reason, a 1.5 kcal/mL solution is chosen. At a rate of 55 mL/h for 20 hours, this formula provides 1650 kcal/d (26.6 kcal/kg) vs the 1296 kcal/d (20.9 kcal/kg) the patient previously received from EN.

Estimations of protein requirements vary from 1.3 g/kg²¹ to more than 2 g/kg²⁰ and are likely affected by concomitant disease states. Given this patient's polytrauma, it may be reasonable to administer a dose of protein even higher than the proposed dose of 1.67 g/kg. With the current formula providing 94 g/L, the patient will receive 103.4 g protein per day over 20 hours (vs the 58.3 g/d she was receiving previously). As discussed in the chapter, immune-modulating formulations should be considered for traumatically injured patients;³ the benefits of ω -3 supplementation in the setting of propofol administration are unknown.

Nutrition in Acute Spinal Cord Injury

Isolated SCI patients have nutrition needs distinct from those of patients with TBI. The physiological rationale for such a difference has been attributed to the difference in neuronal connectivity and stimuli, which results in energy expenditure being lower in patients with SCI than in those with TBI.^{74,75}

Nutrition Requirements

IC measurements for patients after SCI, rather than use of predictive equations, is supported as a level II recommendation in the American Association of Neurological Surgeons and Congress of Neurological Surgeons SCI guidelines.⁷⁴ No validated predictive equation best determines the SCI energy expenditure.⁷⁵ Use of the Harris-Benedict equation with an injury factor of 1.6 and activity factor of 1.2 was initially supported in a 1979 landmark paper by Long and colleagues to estimate post-SCI energy needs.⁷⁶ However, using such approach has been found to overestimate energy requirements.⁷⁷ See Chapter 2 for a general discussion of IC and equations used to predict energy needs.

In a study of 7 patients with TBI and 7 with SCI, the SCI population had 48% lower energy needs than the patients with TBI. Patients with SCI were also found to have a measured energy expenditure that was 56% of what was predicted by the equation proposed by Long and colleagues.⁷⁷

Extent of injury seems to affect energy needs in patients with SCI. Measured resting energy expenditure is lower in patients with higher and more complete SCIs.^{74,78}

Interestingly, patients with SCI seem to have lower-than-predicted metabolic needs long after the acute stages of injury. Bauman and colleagues studied energy expenditure in 13 sets of adult twins with 1 twin having an SCI and the other as a control.⁷⁹ All SCIs occurred 3 to 26 years before the study. The investigators reported that energy expenditure remained low for years following SCI. The measured energy expenditure for the participants with SCI was, on average, 15% less than the energy requirement predicted by the Harris-Benedict equation, and the mean energy requirement for this group was approximately 20.4 kcal/kg. Monroe and colleagues evaluated 10 male subjects with SCI that had occurred at least 2 years before the study. They concluded that the individuals with SCI expended significantly lower daily energy than the control subjects. The lower energy expenditure in those with SCI was explained by lower levels of physical activity, lower resting metabolic rate, and the thermogenic effect of food.⁸⁰

Persistent nitrogen losses have been noted after SCI. This loss seems to be independent of nutrition support high in protein (2 g/kg/d) and energy.⁸¹ The nitrogen loss peaks have been described at about 3 weeks, and ongoing loss may last for 7 weeks.^{82,83} Guideline recommendations focus on meeting energy and nitrogen needs, rather than attempting to achieve a nitrogen balance.⁷⁴ Protein requirements immediately following SCI are estimated to be 1.5 to 2 g/kg/d.⁷⁴

Role of Nutrition

Currently, no data are available to validate that early EN (within 72 hours of injury) improves neurologic outcome after SCI. However, such an approach is regarded as safe and is a level III recommendation in

the SCI guidelines based on 2 studies.⁷⁴ Dvorak and colleagues compared patients receiving early EN (initiated less than 72 hours after SCI) vs late EN (initiated more than 120 hours after SCI) and found no differences in nutrition status, feeding complications, days on mechanical ventilation, infection, or length of stay.⁸⁴ A retrospective review also noted a lack of complications with early EN.⁸⁵

No specific recommendations have been made for the ideal nutrition formulation for patients with SCI.⁷⁴

Special Considerations

Nutrition support after SCI may be complicated by many factors. For example, SCI-related autonomic dysfunction may lead to paralytic ileus or neurogenic bowel and may further affect the patient's ability to feed.⁸²

Glycemic Control

Initial increases in hepatic gluconeogenesis and initial changes in insulin response may result increased lactic acid production and neurotoxicity from increased glucose substrate availability.⁸² This problem could be further complicated by post-SCI methylprednisolone protocols, which are used less frequently than in the past and are no longer recommended in current guidelines.^{86–89}

As in TBI, hyperglycemia in SCI may be deleterious and must be aggressively managed in the acute phase of the injury.⁸² IV or subcutaneous insulin therapy may be used both acutely and chronically to control blood glucose. However, optimal glycemic targets and the effects of intensive insulin therapy for the SCI population remain largely unknown, and specific guidelines for glycemic control are lacking.⁹⁰

Vitamin D Deficiency

Vitamin D deficiency has also been noted in SCI. It can result in hyperparathyroidism and increased bone resorption.^{82,91}

Obesity and Cardiovascular Disease

Long-term management of SCI patients requires special attention to this population's elevated risk of obesity and cardiovascular disease.^{92,93} A modified BMI scale has been proposed for individuals with SCI, with normal weight defined as a BMI of 18 to 22, overweight as a BMI of 22 to 25, and obesity as a BMI of more than 25.⁹³ In a study of 73 individuals with SCI that occurred at least 1 year earlier, Groah reported that nearly 70% of the participants were overweight when assessed using the modified scale; this study also noted deficient intake of some vitamins, minerals, and macronutrients.⁹⁴ Another study evaluated 7959 veterans with SCI and reported that almost 53% were obese or overweight as defined by the standard BMI categories (overweight: BMI, 25.0 to 29.9; obesity: BMI, 30 or greater).⁹⁵ When the BMI scale was adjusted for people with SCI to define overweight as a BMI between 23 and 27 and obesity as a BMI of greater than or equal to 28, 68% of subjects were classified as overweight or obese.⁹⁵

General energy recommendations for weight maintenance in quadriplegic patients are 20 to 22 kcal/kg/d or 55% to 90% of the energy goal estimated by the Harris-Benedict equation.⁹⁶ For paraplegics, energy recommendations are increased slightly to 22 to 24 kcal/kg/d (80% to 90% of the estimate calculated from the Harris-Benedict equation).⁹⁶

Pressure Ulcers

Individuals with SCI in long-term care have protein requirements comparable to those for healthy individuals (0.8 to 1 g protein per kg ideal body weight per day). The estimated protein requirement should be increased if the patient has decubitus ulcers.³ Estimates for the incidence of pressure ulcers in patients with SCI are quite high (25% to 66%). Notably, patients with higher level lesions are more likely to develop pressure ulcers.^{97–99}

In 2009, the National Pressure Ulcer Advisory Panel and European Pressure Ulcer Advisory Panel published guidelines for patients with pressure ulcers, recommending adequate intake of protein (1.25 to 1.5 g/kg/d) and energy (30 to 35 kcal/kg/d), sufficient daily fluid, and vitamin and mineral supplementation if intake is poor or deficiencies are suspected.¹⁰⁰ The guidelines also recommend a consultation with a dietitian to ensure the patient's nutrition needs are being met.^{97,100}

Nutrition in Acute Stroke

Each year, more than 795,000 people in the United States have a stroke.¹⁰¹ Stroke is the fifth leading cause of death in United States. Although more than 80% of patients with stroke survive, many have serious long-term disabilities.¹⁰¹ Nearly 87% of stroke cases are ischemic, and less than 13% are hemorrhagic, intracerebral, or subarachnoid.¹⁰¹

Dysphagia

Besides gross neuromotor and cognitive dysfunction, 78% of stroke patients may experience various aspects of dysphagia. Most patients regain full swallow recovery within a few weeks, but others may take much longer or do not completely recover swallow function.¹⁰²

Dysphagia should be assessed and addressed immediately because swallowing difficulty can contribute to complications of care, including aspiration pneumonia, malnutrition, prolonged rehabilitation, and increased mortality.^{103,104} The Joint Commission dropped the dysphagia screening from the core patient care measures in 2010, but many stroke centers continue to require dysphagia screening before any oral intake, including food, fluid, or medications, can be initiated.² Patients experiencing dysphagia after a stroke have an increased risk of developing dehydration, pneumonia, and possibly chronic malnutrition.¹⁰⁵

Al-Khaled and colleagues screened more than 9000 acute ischemic stroke patients within 24 hours of admission and reported that 25.1% of patients had dysphagia, which independently correlated with increases in mortality (odds ratio [OR] = 3.2; 95% CI, 2.4–4.2; $P < 0.001$) and disability (OR = 2.3; 95% CI, 1.8–3.0; $P < 0.001$) at 3 months after the stroke.¹⁰⁶ Patients with dysphagia had a higher rate of pneumonia than those without (29.7% vs 3.7%; $P < 0.001$). Screening for dysphagia within 24 hours of

admission was associated with decreased risk of stroke-related pneumonia (OR = 0.68; 95% CI, 0.52–0.89; P = 0.006) and disability at discharge (OR = 0.60; 95% CI, 0.46–0.77; P <0.001).¹⁰⁶

Several mechanisms are available for informal bedside screening for dysphagia.¹⁰⁷ Cummings published a successful, easy-to-use dysphagia screening tool that nurses can use to quickly identify dysphagia.¹⁰⁸ Campbell and associates have presented a facility-developed Nursing Bedside Dysphagia Screen as a valid and reliable tool to help identify patients with stroke who are at risk for aspiration pneumonia.¹⁰⁹

Trained personnel should frequently assess stroke patients for dysphagia and evaluate the aspiration risk with the goal to return to “normal” oral consumption. A modified barium swallow evaluation remains the gold standard to diagnose oropharyngeal dysphagia and should be performed when dysphagia is suspected.¹¹⁰

Role of Nutrition Support

When the patient has dysphagia or is unable to maintain volitional intake, nutrition via an enteral access device should be considered because oral nutritional supplements alone may not provide adequate nutrition. The 2005 Feed or Ordinary Diet (FOOD) trial was a series of 3 multicenter, randomized controlled trials that evaluated the use of oral nutritional supplements following a stroke in 4023 patients in 125 hospitals in 15 countries.¹¹¹ The FOOD trial findings showed no beneficial outcomes to support the routine use of oral nutritional supplements to well-nourished hospitalized patients following a stroke.¹¹¹ However, because the FOOD trial studied a well-nourished population, its finding may not apply to patients with a predisposition to or existing protein-energy malnutrition; these patients may see positive results from the routine use of oral nutritional supplements.

Qualified clinicians should use a validated tool, such as Nutrition Risk in Critically Ill (NUTRIC) or Nutrition Risk Screening (NRS-2002), to assess all stroke patients admitted to the ICU for nutrition risk.^{112,113} The 2016 ASPEN and SCCM guidelines recommend that EN be initiated within 24 to 48 hours of admission for all critically ill patients at high nutrition risk and for others with anticipated prolonged nil per os (nothing by mouth) status.³ Most stroke patients should tolerate EN and not require PN unless they have preexisting physical or physiological impediments to EN.

EN should be advanced to the optimal rate or volume with added modulars as needed within 24 to 72 hours of initiation. In a study of patients with acute stroke and dysphagia, Zheng et al compared those who received early EN with those fed by orally by their family and found that the group receiving early EN had better nutrition status and reduced nosocomial infection and mortality rates after 21 days.¹¹⁴ In a study of 273 comatose acute stroke patients, Yamada found that the use of early PN along with a 20% glucose solution via a feeding tube was beneficial but also recommended that early PN not be administered for longer than 10 days because switching to EN after initial PN contributed to better nutrition recovery than the extended use of PN.¹¹⁵

Most stroke patients tolerate EN with a gastric feeding access, commonly with a bedside-placed nasogastric feeding tube. A bridle may be used to secure the nasally inserted tube to deter unintentional

dislodgement.^{116–119} The feeding tube should be diverted to the small bowel if the patient is at risk for aspiration of gastric contents.³

Prospective randomized studies have not been done on the optimal timing of placement of percutaneous endoscopic gastrostomy (PEG) tubes or gastrostomy tubes (G-tubes). Therefore, timing is based on clinical judgment, experience, and patient condition. The American Stroke Association recommends that a secure G-tube be considered when EN is expected to be necessary for more than 4 weeks.¹²⁰ Many acute rehabilitation hospitals and long-term care facilities require a more secure type of enteral access before the patient is transferred. However, a G-tube or PEG tube does not prevent complications from aspirations of oral pharyngeal secretions, and placement carries some risk; therefore, selection of appropriate candidates for G-tube placement is important.

The FOOD trial reported that early EN was associated with an absolute reduction in risk of death of 5.8% and a reduction in death and poor outcome of 1.2%; however, in stroke patients with dysphagia, early PEG placement/feeding was associated with increased risk of death or poor outcome compared with nasogastric feedings.¹²¹

Conversely, Geeganage and colleagues reviewed 33 studies with 6779 participants from the Cochrane Library stroke group and reported that data were insufficient to make specific recommendations on the effects of swallow therapy, feeding, and nutrition support on functional outcome and death in patients with dysphagia following stroke. The review reported that, compared with G-tube feeding, nasogastric feeding reduced treatment failures and GI bleeding, and nasogastric feeding had higher nutrition delivery for long-term therapy. Nutritional supplementation was associated with fewer pressure sores and increased energy and protein intake.¹²²

Limited physical activity, dysphagia, aspiration, constipation, adverse effects of anticholinergic drugs, depression, and skin breakdown all contribute to nutrition complications in the stroke population. Jiang et al investigated risk factors that predicted short-term mortality in poststroke patients with persistent dysphagia following a PEG placement.¹²³ The 3 risk factors associated with increased risk for mortality for PEG insertion were age, American Society of Anesthesia score, and pre-PEG insertion serum albumin levels.¹²³ Jiang and colleagues suggest that assessment of patients for these 3 risk factors could help identify patients likely to survive more than 3 months following a PEG insertion.¹²³

Healthcare providers should inform patients and family members that the G-tube or PEG tube is not necessarily a permanent form of feeding access and can be easily removed when dysphagia resolves.^{124,125} See Chapter 12 for additional information on enteral access devices.

Nutrition Requirements

Energy requirements of stroke patients may vary depending on whether the acute stroke is ischemic or hemorrhagic. IC is the gold standard for determining the energy requirements.³ No equation has been validated to precisely determine the energy expenditure for the stroke population, and estimating the degree of hypermetabolism following stroke remains controversial.

Finestone and colleagues prospectively evaluated 91 first-event ischemic and hemorrhagic stroke patients, comparing measured and estimated energy requirements of this population.¹²⁶ On average, the measured energy expenditure was 107% to 114% above the energy requirement estimated by the Harris-Benedict equation and did not significantly change over a 90-day period. Based on their findings, the authors concluded that the stroke patient population shows a lack of a hypermetabolic response following injury. Their measurements did not significantly vary between ischemic and hemorrhagic stroke patients, but it should be noted that 84% of patients studied had ischemic stroke and SAH patients were excluded.¹²⁶

Bardutzky also reported a lack of hypermetabolism following a stroke and found that measured energy expenditure closely correlated to estimates using the Harris-Benedict equation.¹²⁷ Nagano et al compared several predictive equations in patients with ischemic stroke and reported the Harris-Benedict equation provided the prediction closest to energy expenditure measured by IC.¹²⁸

Two studies suggest that hemorrhagic stroke patients elicit a more hypermetabolic response than those with ischemic stroke.^{129,130} Esper et al measured energy expenditure in 14 nontraumatic intracerebral, intraventricular, and SAH patients who exhibited a hypermetabolic response. The median measured energy expenditure was 126% (range: 101% to 170%) above the estimate from the Harris-Benedict equation.¹²⁹ Frankenfield and associates compared energy expenditures of 30 ischemic stroke, 36 hemorrhagic stroke, and 32 TBI patients.¹³⁰ The ischemic stroke population was the least hypermetabolic, likely because these patients had a lower incidence of fever and lower average body temperature. The hemorrhagic stroke population exhibited a hypermetabolic state with measurements similar to those of the TBI population. Both stroke types were accurately predicted by the Penn State equation 72% of the time.^{130,131} See Chapter 2 for additional information on the Penn State equation.

Kasuya et al reported severe hypermetabolism in 36 patients following SAH, with measured energy expenditures ranging from $139\% \pm 32\%$ to $198\% \pm 78\%$ of the resting energy expenditure predicted by the Harris-Benedict equation.¹³² The highest energy needs of these SAH patients occurred at Day 10 following injury (coinciding with the typical apex of vasospasm risk).¹³² Badjatia and coauthors prospectively observed 229 patients following SAH.¹³³ They defined the inflammatory-mediated hypercatabolic response following SAH as a ratio of C-reactive protein to transthyretin (prealbumin).¹³³ This ratio correlated with a negative nitrogen balance and overall poor outcome at 3 months. In this cohort, 53 patients (23%) developed hospital-acquired infections following SAH.¹³³ Lower energy intake (less than 11.3 kcal/kg/d; $P = 0.02$) and greater negative nitrogen balance (more than -8.8 g/d; $P = 0.001$) were both associated with the development of hospital-acquired infections in these patients.

Based on available data, the energy requirements following an ischemic stroke are likely close to estimated basal metabolic needs as determined by the Harris-Benedict equation or Penn State equation. Data suggest that patients with hemorrhagic stroke, especially SAH, have elevated energy needs as compared with estimates of basal metabolic requirements.

Energy needs will change as the patient recovers and will reflect whether the patient participates in rehabilitation physical therapy or remains with limited physical activity. Nutrition support should be

reassessed and adjusted to minimize excessive or unnecessary weight gain or weight loss, prevent micronutrient and macronutrient deficiencies, and address any skin breakdown that occurred following the stroke. Use of a nutrition-focused physical examination can help identify any new onset of malnutrition.

Protein requirements should be determined by assessing the patient's prestroke nutrition status and renal and liver function immediately following the stroke. The recommended protein goals range from 1 to 1.5 g/kg/d.¹³⁴ Prealbumin and albumin often decline secondary to brain injury as an acute-phase response; therefore, neither prealbumin nor albumin accurately assesses nutrition status in the immediate poststroke and critically ill patient.³ Evidence of protein-energy malnutrition, recent weight loss, or wounds or skin breakdown indicate a higher protein requirement. Patients requiring hemodialysis or continuous renal replacement therapy also have increased protein requirements.^{3,135} Clinicians should monitor ongoing changes in protein requirements and adjust the protein in feedings accordingly, until the patient consumes nutritionally adequate oral intake.

Refeeding syndrome, a rapid depletion of serum potassium, magnesium, and phosphorus, can occur in the stroke population when nutrition support, specifically carbohydrates, is initiated.¹³⁶ This phenomenon most frequently occurs after aggressive EN or PN is initiated following a hypermetabolic injury, after prolonged underfeeding, and in chronically malnourished or alcoholic patients. The depleted serum electrolytes, especially phosphorus, make it difficult to wean the patient from the ventilator. Severe hypokalemia and hypomagnesemia can result in deleterious cardiac, GI, and mental status changes. Frequent initial electrolyte monitoring and aggressive thiamin and electrolyte replacement protocols help avoid refeeding syndrome in the critically ill stroke population.¹³⁶

Most stroke patients tolerate a standard polymeric enteral formula with 1 to 1.5 kcal/mL unless malabsorption or a GI disease was present prior to the stroke.¹³⁴ de Aguiar-Nascimento and associates reported that, compared with standard casein protein formulas, a whey protein formula may contribute to decreased inflammation following an ischemic stroke.¹³⁷

If hypernatremia protocols aim for serum sodium ranges of 140 to 150 mEq/L to minimize cerebral edema, a concentrated enteral formula with 1.5 to 2 kcal/mL may be appropriate to provide less free water. Once the free-water restriction is liberated, modifying the enteral formula to a more-dilute feeding of 1.2 to 1.5 kcal/mL provides more free water continuously without the need for large bolus free-water administration, which can contribute to GI intolerance. To avoid dehydration, more-dilute formulas with 0.8 to 1.2 kcal/mL can meet all necessary daily free-water needs for patients who require long-term EN.

Clinicians should assess whether patients receive the Recommended Daily Intake (RDI) of vitamins/minerals from EN. A multivitamin with minerals can be given daily if the total volume of enteral formula does not provide 100% of the RDI. Crushable multivitamin-multimineral tablets often provide more vitamins and minerals than prepackaged liquid preparations. Supplements of individual micronutrients may be appropriate if they are not included in the EN regimen or if patients experience excessive losses.

The VITATOPS study evaluated 8164 patients and concluded that daily folic acid and vitamin B6 and B12 supplements did not reduce the recurrence of an ischemic stroke.¹ In a meta-analysis of 18 trials with 57,143 individuals, Zhang and colleagues also found that high-dose B vitamin supplementation was not associated with a lower risk of stroke.^{138,139} Further studies are needed to provide evidence about high-dose vitamin/mineral therapies and their effect on secondary stroke prevention.

Practice Scenario 22-2 describes a nutrition support regimen that meets the needs of a patient with dysphagia after an ischemic stroke.^{126,127,134}

Practice Scenario 22-2

Question: What is the appropriate nutrition support regimen for a patient with dysphagia following an ischemic stroke?

Scenario: A 64-year-old woman (weight, 63 kg; height, 165 cm) presented to the emergency department with a potential stroke 8 hours after her first symptoms of a sudden fall, right-side weakness, facial droop, and slurred speech. Computed tomography of the head revealed left middle cerebral artery thrombus and was negative for hemorrhage. The patient did not receive tissue plasminogen activator (tPA) in the emergency department because the timing was beyond the window when tPA provides benefit. Her past medical history included chronic obstructive pulmonary disease (COPD), hypertension, hyperlipidemia, and cataracts. Because of her history of COPD, the patient could not be extubated from mechanical ventilation for 8 days after a thrombectomy. She had residual weakness and slurred speech, and she failed a bedside swallow evaluation after extubation. Laboratory data included blood glucose, 122 mg/dL, and albumin, 3.3g/dL.

Intervention: A nutrition support consult was ordered. A nasal feeding tube was placed on Day 2 in the intensive care unit. Indirect calorimetry (IC) indicated energy expenditure of 1390 kcal/d. A standard polymeric enteral formula (1.2 kcal/mL and 60 g protein per liter) was ordered to be administered at 50 mL/h to provide 1440 kcal/d and 72 g protein per day. Medications were administered enterally. Once maintenance intravenous fluids were stopped, free water was supplemented at 200 mL 4 times daily.

Answer: Enteral nutrition via a nasoenteric feeding tube with energy requirement directed by IC is appropriate in this scenario. The patient's protein needs were 63 to 95 g/d (1 to 1.5 g/kg/d).^{126,127,134}

Rationale: When a patient has had a stroke and experiences dysphagia that prevents oral intake, the nutrition support regimen must meet the patient's needs for energy, protein, micronutrients, and fluids.

Dysphagia and Oral Intake

Not all stroke patients demonstrate dysphagia severe enough to necessitate EN. Dysphagia can present as oropharyngeal or esophageal dysfunction, and, therefore, proper diagnosis and management are

critical to avoid aspiration, malnutrition, and acute and chronic dehydration. A speech and language pathologist can determine the dysphagia etiology and recommend appropriate strategies to avoid or minimize aspiration. These therapists and other qualified clinicians should teach patients and caregivers about interventions and swallowing techniques and can recommend a variety of dysphagia diets to be used as the patient recovers or transitions off EN.

The National Dysphagia Diet, published in 2002 by the American Dietetic Association, defined a standardized terminology for specific dietary texture modifications and liquid viscosities.¹⁴⁰ The National Dysphagia Diet has 3 levels of modified diets and 4 levels of liquid viscosity. The level 1 diet is pureed (homogenous, very cohesive, and pudding-like in texture, requiring very little chewing ability). The level 2 diet is mechanically altered (cohesive, moist, semisolid foods, requiring some chewing) and is followed by the advanced level 3 diet (soft foods that require more chewing).¹⁴⁰ Liquid consistencies are spoon-thick viscous, honey-thick viscous, nectar-like viscous, and thin liquids.¹⁴¹ Once cleared to consume oral nutrition, the patient with the most severe dysphagia initiates the level 1 diet, progresses toward levels 2 and 3, and eventually resumes a regular diet if the dysphagia has resolved.

Nutrition in Acute Neurologic Injury Rehabilitation

Preadmission Considerations

Early initiation of rehabilitation after acute neurologic injury is cost effective and has significant effects on outcome measures and lifetime care costs for patients with stroke or TBI.^{142,143} Patients with SCI, TBI, or stroke who qualify for acute rehabilitation are transferred within the first few weeks following the initial injury. Acute rehabilitation facilities accept patients who have the potential to respond to intensive therapy targeting progress toward activities of daily living. Patients participate in multiple sessions of physical therapy, occupational therapy, and, if applicable, speech and language therapy for 3 to 6 hours per day for a 2- to 6-week period. Interdisciplinary teams of therapists, nurses, physicians, and pharmacists work closely with families and patients to set functional recovery goals.

Baseline cognitive and physical function affects decisions on medications and nutrition care regimens employed in the acute rehabilitation period. Well-designed studies of nutrition requirements during this transition period are needed. As patients make progress, their energy requirements, supplement needs, routes of nutrition intake, and medications continually evolve. Risks of malnutrition are affected by preinjury nutrition status, the effectiveness of nutrition during acute care, and any cognitive and physical limitations associated with the neurologic injury.

Baseline Nutrition Status on Admission

On admission to the acute rehabilitation facility, the patient's baseline weight, BMI, and standard nutrition-related laboratory data must be assessed and documented.¹⁴⁴ Liver function tests are important because medications used in rehabilitation may exacerbate preexisting inflammation from hepatitis or other injury mechanisms. Medications and the nutrition history should be examined for potential confounding of nutrition recommendations during the rehabilitation program (Table 22-3).^{14,18,42,43,120,145} Effective nutrition strategies require collaborative discussions between dietitians

and other members of the interdisciplinary team. Therapists are key partners in mobilizing patients to avoid decubiti development, introduce physical activities to stimulate hunger, and educate patients on methods to restore oral intake when possible. Maintaining communication among team members facilitates optimal nutrition intake as the patient progresses throughout the rehabilitation program.

TABLE 22-3 Medication Considerations in Long-Term and Acute Care Rehabilitation

Medication Type or Name	Indication	Nutrition Considerations
Atypical antipsychotics (quetiapine)	Agitation/aggression	Weight gain; increased appetite; metabolic changes in glucose, triglycerides, and cholesterol; dysphagia; drug interaction with erythromycin; potential for prolonged QT interval
Amantadine	Cognitive stimulation	Altered GI motility; appetite reduction; avoid oral potassium supplements; may decrease GI stimulation response to erythromycin
Bromocriptine	Cognitive stimulation	Altered GI motility; appetite reduction; elevated AST, ALT, and alkaline phosphatase levels
Levodopa/carbidopa	Cognitive stimulation	Drug interactions: vitamin B ₆ stimulation of carbidopa metabolism; metoclopramide; iron
Methylphenidate	Cognitive stimulation/attention	Decreased appetite; weight loss; herbal supplement interactions
Donepezil	Attention/memory	Altered GI motility; decreased appetite; weight loss
Atomoxetine	Attention	Altered GI motility; weight loss; decreased appetite
Lisdexamfetamine	Attention	Altered GI motility; weight loss; decreased appetite; drug interactions with potassium citrate, magnesium supplements; sodium bicarbonate; caffeine; and herbal supplements
Selective serotonin reuptake inhibitors (sertraline, citalopram)	Depression	Hyponatremia; SIAD; altered GI motility; may cause hepatotoxicity; interactions with multiple herbal supplements, metoclopramide, erythromycin
Melatonin	Sleep	May alter glucose tolerance
Trazodone	Sleep	Hyponatremia; SIAD; hepatotoxicity; altered GI motility; interactions with erythromycin, chondroitin, ω-3 supplements, and multiple herbal supplements
Topiramate	Headache	Metabolic acidosis; hypokalemia; hyperammonemic encephalopathy; decreased appetite; weight loss; altered GI motility; taste changes; interactions with metoclopramide, herbal supplements
Baclofen (oral/intrathecal routes available)	Spasticity	Altered GI motility; weight gain; interactions with magnesium citrate, metoclopramide, and herbal supplements
Tizanidine	Spasticity	Constipation; elevated AST/ALT levels; vomiting; interactions with caffeine, herbal supplements, and metoclopramide
Dantrolene	Spasticity	Hepatotoxicity; nausea; diarrhea; interactions with herbal supplements, metoclopramide
Benzodiazepines (diazepam, clonazepam)	Spasticity	Altered GI motility; elevated AST/ALT levels; appetite changes; interactions with metoclopramide, herbal supplements
Gabapentin	Neuropathic pain; spasticity	Altered GI motility; weight gain; interactions with iron supplements, magnesium, herbal supplements, and metoclopramide
Botulinum toxin	Spasticity	Dysphagia; nausea; interaction with magnesium
Warfarin	Stroke guidelines, ¹²⁰ deep vein thrombosis	Interactions with erythromycin, orlistat, coenzyme Q, fish oils, herbal supplements, and vitamin K from nutritional formula, oral supplements, and oral diet components

ALT, alanine transaminase; AST, aspartate transaminase; GI, gastrointestinal; SIAD, syndrome of inappropriate antidiuresis.
Source: Data are from references 14, 18, 42, 43, 120, and 145.

Nutrition Goals During Acute Rehabilitation

Nutrition adequacy as a predictive component affecting rehabilitation outcomes is not routinely captured in database models used in research.^{146,147} Traditional endpoints such as weight gain, improved anthropometrics, or metabolic improvements are not readily accessible in these data sets. Functional independence measures of motor and comprehension progress during rehabilitation include

feeding scores. Recently, data from the Traumatic Brain Injury Model Systems National Database were retrospectively examined to create a prognostic model for rehabilitation admission factors affecting discharge destination.¹⁴⁷ Feeding and bowel and bladder management scores were significantly lower in participants discharged to another institution compared with those returning to a private residence. Although feeding did not become a final predictive factor in the proposed model, these results highlight the importance of addressing nutrition goals throughout the acute rehabilitation stay.¹⁴⁸

Energy goals should be adjusted during rehabilitation to create a balanced postinjury diet that maintains muscle mass and allows the patient to participate in activities of daily living once transferred to home. Measurement of energy expenditure by IC is not routinely done in acute rehabilitation. Predictive equations have not been validated in TBI, stroke, and SCI patients participating in acute rehabilitation.

In ventilator-dependent SCI patients, multiplying the estimated energy requirement calculated from the Harris-Benedict equation by an activity factor of 1.1 and a stress factor of 1.2 provided a strong correlation between measured and predicted energy expenditures.¹⁴⁹ Acute SCI and TBI patients followed over a 3-week inpatient period (nonrehabilitation) showed marked differences in energy and nitrogen balance.⁷⁷ Intake of less than 20 nonprotein kcal/kg/d and mean protein intakes less than 1 g/kg/d resulted in positive energy balance for patients with SCIs, but nitrogen balance remained negative. In contrast, TBI patients fed more than 25 nonprotein kcal/kg/d and mean protein intakes greater than 1 g/kg/d were in negative energy and nitrogen balance.⁷⁷ These data demonstrate the persistent risk of muscle loss in both SCI and TBI patients as well as a stark difference in the energy demands between these populations.

Total daily energy expenditure after SCI is reduced by 12% to 54%, depending on injury level, activity, and lean body mass.⁹³ Mean energy expenditures of 22.7 kcal/kg/d and 27.9 kcal/kg/d were measured in tetraplegic and paraplegic rehabilitation patients, respectively.⁷⁸ Patients gained 1.7 kg/wk when the diet was not controlled and more than 1700 kcal/d were consumed.

Recently, older SCI subjects in acute rehabilitation reported energy intakes higher than 1900 kcal/d and protein intake greater than 70g/d.¹⁵⁰ Nutrition intake was identified as a modifiable risk factor for obesity-related complications affecting this population.¹⁵⁰ This study also reported energy and protein intake in patients with TBI, new onset stroke, and Parkinson's disease during acute rehabilitation. Energy intake was greater than 1500 kcal/d for individuals with TBI and 1400 kcal/d for those who had a stroke and for patients with Parkinson's disease. Protein intake was greater than 61 g/d for patients with TBI and greater than 55 g/d for the stroke and Parkinson's disease patients. Subjects in the SCI group were younger than those in the TBI, stroke, or Parkinson's disease groups and were identified as the group at highest risk for overeating.¹⁵⁰

Although overeating creates risks for SCI patients, poor intake may increase the risk of pressure ulcers. When pressure ulcer incidence was examined in SCI patients, a higher percentage of underweight patients developed pressure ulcers compared to healthy weight, overweight or obese patients with SCI.¹⁵¹ Monitoring weekly weight changes throughout the rehabilitation program is useful in guiding adjustments in energy requirements.

When selecting enteral formula for patients in acute rehabilitation, nutrition support clinicians should consider the patient's higher demand for protein replacement; products designed to deliver higher protein content may be preferable. The evidence on specialized enteral formulas, branched-chain amino acids, glutamine, arginine, and fish oil supplements is insufficient to support routine use of these products during acute rehabilitation of patients with neurologic injuries.

Limited studies in neurologic patients during acute rehabilitation suggest that total energy intake should be controlled.¹⁵⁰ Using admission body weights for SCI, TBI, stroke, and Parkinson's disease patients, average energy intake ranged between 19.2 and 24.4 kcal/kg.¹⁵⁰ Macronutrient formulation tolerance may be monitored by routine testing of blood chemistries, prealbumin, hepatic function, and triglycerides.

Special Considerations

Hormonal Issues

Pituitary dysfunction has the potential to significantly affect the metabolic tolerance and traditional monitoring parameters of the nutrition regimen.¹⁵² The growth hormone-IGF-1 system is altered following brain injury.^{23,24} Dysfunction of sodium homeostasis is common. Hypothyroidism is a common finding in patients with TBI.^{35–37} Thyroid replacement, growth hormone, and sodium modulators may affect patients' responses to a nutrition regimen and the monitoring of that regimen.

Protein Loss

Continued protein losses up to 2 months' postinjury with negative nitrogen balances have been reported in SCI patients.¹⁵³ Collecting urine to measure nitrogen loss in patients with SCI can be a challenge unless catheters are in place. Incontinence episodes may also complicate assessment of urinary nitrogen loss in patients with other types of neurologic injuries. Serial anthropometrics or body mass analysis may be informative options for assessing protein dosing adequacy and muscle maintenance for some patients.

Formula Efficacy and Gastrointestinal Tolerance

The assessment of formula effectiveness must include careful examination of GI intolerance, which can significantly limit participation in physical therapy and predispose patients to other complications.

Micronutrient Deficiencies

Micronutrient deficiencies reported in patients with neurologic injuries include folic acid, zinc, selenium and, most recently, vitamin D.^{24,154,155} Reduced concentrations in vitamin D have been reported in SCI and TBI patients in acute and outpatient rehabilitation settings.^{156,157} In 101 acute rehabilitation patients, 77% were deficient in vitamin D at admission.¹⁵⁶ In addition to osteopenia, muscle weakness, and impaired physical function, vitamin D deficiencies were associated with higher in-hospital mortality in neurocritical care patients.¹⁵⁸

Vitamin D may act as a “neurosteroid,” and replacement should be considered for acute rehabilitation patients with neurologic injuries.¹⁵⁵ Patients with serum 25-hydroxyvitamin D concentrations below 20 ng/mL should be treated with 6000 IU cholecalciferol daily or 50,000 IU once a week for 8 weeks to achieve a serum 25-hydroxy vitamin D level greater than 30 ng/mL.¹⁵⁹ Once stabilized, patients should receive maintenance cholecalciferol doses of 1500 to 2000 IU/d.¹⁵⁹

Weight Management

The long-term nutrition goal for patients with neurologic injury is to provide a diet optimized for weight management given the projected activity level of the patient.¹⁶⁰ Patients with SCI and stroke have reported changes in muscle mass when diets are not modified. In a multicenter longitudinal study, 5 years after discharge from acute inpatient rehabilitation, 56% to 75% of SCI patients were classified as overweight or obese.^{161,162} Obesity increases the risks of medical complications, rehospitalization, and poor functional outcomes.¹⁵⁰ Educating patients and caregivers about dietary modification strategies to include more protein, less fat, and controlled carbohydrates may help reduce long-term metabolic complications.

Fluid Therapy

Fluid therapy can be a unique challenge in the acute rehabilitation population. Independent intake goals for oral ingestion of electrolyte water products, protein shakes, and normal food allow the patient to manage daily fluid totals. After patients have a stroke or TBI, challenges with movement and memory may significantly affect independent intake. Patients are at risk for dehydration, and administration of fluid bolus by nursing is often required. Dehydration is exacerbated by activities or infections as well as limited oral intake. If dehydration is not addressed, patients are at increased risk of renal insults when antibiotics (eg, vancomycin, penicillin), nonsteroidal pain medications, or diuretics are administered. Dosing adjustments for maintenance medications may also be required to prevent dehydration.

Accurate fluid monitoring may be difficult because the collection and measurement of urine output are often imprecise in the acute rehabilitation setting. Medical complications of neurologic injury include urinary retention, constipation, and diarrhea.^{74,82,163} When setting fluid therapy goals, clinicians should consider the patient’s functional status for bladder and bowel. As patient independence increases, normalizing routines for bladder and bowel emptying is encouraged, but that can make the collection of urine for measurement impractical. Nonambulatory patients may have poor bladder control and require incontinence pads. Urinalysis results for specific gravity and sodium are useful for guiding fluid intake adjustments. This assessment becomes particularly important when patients receive desmopressin for sodium management following TBI.^{22,36} Hypotension or dizziness from poor fluid management may increase fall risks in this predisposed patient population.

Dysphagia

Nutrition-related strategies are affected by the patient’s swallowing status and goals for achieving improvement in activities of daily living. Patients with higher levels of SCI are at greater risk of dysphagia complications and may experience altered taste, smell, or appetite.¹⁶⁴ Gastrostomy devices may be

required to achieve nutrition goals until patients stabilize effective oral intake. Enteral formulations may be delivered via existing PEG tubes in many cases, and clinicians deciding whether to remove these devices will consider return of swallowing skills during or following acute rehabilitation.¹⁶⁵ Bolus dosing is often used during rehabilitation and avoids the use of cumbersome poles that affect ambulation. In a prospective multicenter observational study of patients with severe TBI, those with weight loss at 3 months after injury and continued PEG requirements for feeding were at increased risk of complications and poor outcome independent of injury severity.¹⁶⁶

Optimally, patients progress to oral diets. However, they may still require energy and protein supplements for some time. Dysphagia assessments and training by speech and language therapists facilitate patients' advancement to oral diets. Despite a report that dysphagia diets did not improve intake compared with regular diets following acute stroke, neurologic rehabilitation patients must be cautiously assessed before regular diets are introduced.¹⁶⁷ Once swallowing tests confirm that an oral diet can be safely introduced, clinicians can design formal progress plans to guide individualized recovery of eating skills.

Medications and Dietary Supplements

Use of probiotics, stool softeners, pain medications, cognitive stimulants, anticoagulants, mood modulators, and chronic maintenance medications creates complex medication regimens for neurologically impaired patients.^{163,168} Preinjury and rehabilitation admission medications should be routinely reviewed for potential interactions with nutrition treatment goals and monitoring endpoints.

Clinicians should ask patients and families to identify any nonprescription medications or herbal supplements used by the patient, because these products may potentially interact with prescription medications used following neurologic injury. Information on drug-herbal interactions is available from the National Center for Complementary and Integrative Health,¹⁶⁹ MedlinePlus from the National Library of Medicine,¹⁷⁰ and pharmacy medication resources. See Chapter 19 for more information and resources on dietary supplements.

Appetite stimulants (eg, megestrol, dronabinol, mirtazapine, cyproheptadine) should only be recommended after review for potential drug interactions.

Use of methylene blue for assessment of aspiration risks with EN is no longer recommended. If it is used, clinicians must be aware that some routine medications have serious interactions with this agent.

Chronic Neurologic Diseases

Inpatient nutrition therapy for patients with chronic neurologic diseases presents considerable challenges. Patients may be more prone to having dysphagia, nutrition deficiencies, and drug-nutrient interactions. Special care is needed when assessing patients with these disease states.

Amyotrophic Lateral Sclerosis

ALS (also known as Lou Gehrig's disease) is a rapidly progressing, degenerative motor neuron disease that results in significant muscle weakness and atrophy.

Weight Loss and Malnutrition

Approximately 75% of patients with ALS will experience bulbar involvement, which includes the muscles that control speech, swallowing, and chewing and can lead to substantial weight loss. Causes of weight loss in patients with ALS include dysphagia, upper limb motor difficulties, weakness of tongue and other oropharyngeal muscles, loss of appetite, dyspnea, depression, and hypermetabolism.^{171–174}

Malnutrition is an independent prognostic factor of ALS survival, with an 8-fold increase in risk of death when the patient is of poor nutrition status.^{175–177} Malnutrition is defined as greater than 10% loss of body weight during the course of illness, in conjunction with BMI less than 18 for adults between the ages of 18 and 65 years or BMI less than 20 for patients older than 65 years.¹⁷⁸ Approximately 16% to 53% of patients with ALS are malnourished.^{179,180} With every weight loss of 5% from the time of diagnoses, there is a twofold increase in mortality.¹⁷² Early nutrition intervention in patients with ALS has been shown to maintain good nutrition status for a longer period of time.¹⁸¹

Dysphagia

An estimated 81% of patients with ALS experience dysphagia and may require modified diet textures and thickened liquids.^{177,178} Patients may be unable to meet their nutrient needs via diet alone, and many require EN. EN administered by PEG tubes often replaces or augments an oral diet, and PEG tube placement earlier in the disease process is more effective in preserving nutrition status for a longer period of time.^{171,178,182} The American Academy of Neurology ALS practice parameters recommend PEG tube placement while forced vital capacity is more than 50% of predicted value or when the patient has dysphagia or a BMI less than 20 or loses 5% to 10% of usual body weight.¹⁸³

Energy and Protein Requirements

When determining nutrition needs, the clinician should assess the stage of progression of ALS, because patients initially are in energy balance.¹⁷³ As ALS progresses, the resting metabolic rate increases, and patients typically experience an energy deficit.¹⁷³ The Mifflin–St. Jeor and Harris-Benedict equations have been shown to be the most accurate methods to estimate energy needs, with the Harris-Benedict equation being the most practical.¹⁷³ Some research supports increasing the calculated resting energy expenditure by 10% when determining energy needs for patients with ALS.^{173,178} Genton and colleagues recommend estimating energy needs to be 120% greater than basal energy expenditure measured by IC, and 130% greater than energy requirements predicted by the Harris-Benedict equation.¹⁸⁰ As patients with ALS lose muscle mass, the ratio of organ mass to muscle mass increases, which increases the amount of energy per kg fat-free mass.¹⁷⁸ Because of these changes, patients with ALS may require 34 to 35 kcal/kg/d.¹⁷⁸ Protein requirements for this patient population range from 0.8 to 1.2 g/kg/d.^{172,183}

Approximately 50% of patients with ALS are hypermetabolic; the reason for the hypermetabolism is unknown.^{174,178} Theoretically, with the loss and atrophy of muscle mass, reduced physical activity, and denervation, the ALS patient should have a reduced metabolic demand, but this has not been demonstrated.¹⁷⁸ Several theories have been proposed to explain why this patient population is hypermetabolic, including variations of increased work of both skeletal and respiratory muscles because of muscle loss or increased spasticity, and mitochondrial dysfunctions.^{174,178}

Micronutrient Requirements

The role of antioxidants and other micronutrients in ALS is not fully understood, although several studies have been done. Creatine monohydrate, coenzyme Q10, selenium, and vitamins C, E, and D have been studied in relation to slowing the progression of ALS, but no large-scale studies have reported definitive benefits. At this time, recommendations cannot be made regarding micronutrient supplementation in patients with ALS.^{178,183}

Epilepsy/Seizures

The ketogenic diet—which has been well documented as a therapy for controlling seizures in the pediatric population—is being used with increasing frequency and success in the adult population.^{184–188} The exact antiepileptic mechanism of action of the ketogenic diet is unknown. Several theories suggest it is related to changes in the nerve cell lipid membranes or neurotransmitter production.¹⁸⁹

Specific energy needs are not addressed in the literature on epilepsy. However, to decrease frequency of seizures, a 4:1 ratio of fat to carbohydrate and protein is recommended; this ratio can be titrated down as the disease state stabilizes.^{184,190}

Many medications contain carbohydrates, which must be considered as dietary goals for carbohydrate intake are set. See Table 22-4 for a list of ingredients with carbohydrates.¹⁹¹

TABLE 22-4 Carbohydrate and Noncarbohydrate Ingredients

Carbohydrate ingredients:

- Glycerin
- Maltodextrin
- Magnasweet
- Organic acids: ascorbic acid, citric acid, lactic acid
- Propylene glycol
- Sugars: dextrose, fructose, glucose, lactose, sucrose, sugar, palm sugar, agave nectar, cane syrup, cane juice, corn syrup, honey
- Sugar alcohols: erythritol, isomalt, glycerol, mannitol, maltitol, sorbitol, xylitol
- Starches: cornstarch, hydrogenated starch hydrolysates (HSH), pregelatinized starch, sodium starch glycolate

Noncarbohydrate ingredients:

- Asulfamine potassium (AceK)
 - Aspartame
 - Carboxymethylcellulose
 - Cellulose
 - Hydroxymethylcellulose
 - Magnesium stearate
 - Microcrystalline cellulose
 - Polyethylene glycol
 - Saccharine
 - Superose
 - Stevia (rebiana)
-

Source: Adapted with permission from reference 191: The Charlie Foundation for Ketogenic Therapies. Carb/non-carb ingredients. <http://www.charliefoundation.org/resources-tools/resources-3/low-carb/item/1137-carbohydrate-non-carbohydrate-ingredients>. Copyright © 2016 The Charlie Foundation.

A modified Atkins diet (a 1:1 ratio fat to protein and carbohydrate) can be used once a patient's seizure frequency is more stable. The modified Atkins diet has shown to reduce seizures in adult and adolescent patients with drug-resistant epilepsy.¹⁸⁷

Compliance with the ketogenic and modified Atkins diets by patients who can take an oral diet is low because the diets are unpalatable and rigid.^{187,192} Extreme diet modifications should be used in conjunction with anticonvulsant therapy prescribed by the medical team.

Antiepileptic therapy can increase vitamin D elimination; however, a study compared patients with epilepsy and those without the disease, and both groups had equally low levels of vitamin D.¹⁹³ Recommendations for micronutrient supplementation in adults who are on the ketogenic diet would be premature because of the lack of studies that address this subject. Only a limited number of case reports have been published about this patient population. More research is needed before definitive nutrition recommendations can be made.

See Practice Scenario 22-3 for discussion of the use of EN for an adult patient with intractable seizures.^{172–176,187,188,190,192,194–198}

Practice Scenario 22-3

Question: How can the ketogenic diet (via enteral formula) be used as a therapy for intractable seizures?

Scenario: A 27-year-old male patient is admitted from an outside hospital with refractory generalized convulsive status epilepticus. He is on mechanical ventilation and has been in a pentobarbital coma for nearly 2 weeks, in addition to receiving multiple antiepileptic drugs. The cause of seizures is still being investigated; however, in the meantime, the clinical team would like to try using the ketogenic diet to decrease the frequency of seizures.

Intervention: The physician adjusts intake of pentobarbital and dextrose-containing medications (including propofol, which contains glycerol), and the patient is to be put on a 48-hour fast. The following initial laboratory tests are done:

- Baseline beta-hydroxybutyrate level
- Fasting lipid panel
- Aspartate transaminase (AST)/alanine transaminase (ALT)
- Prealbumin
- C-reactive protein

- Vitamin C
- Zinc
- 25-hydroxyvitamin D
- Carnitine (total, acyl)
- Lactic acid
- Pyruvic acid

Triglyceride and cholesterol levels are normal, indicating that the high-fat ketogenic diet will not pose undue risk of cardiovascular complications or pancreatitis. The clinicians evaluate the patient's energy needs, because the provision of protein will be deficient on this diet. They initiate a ketogenic enteral formula with a 4:1 ratio of fat to protein and carbohydrate and monitor the following laboratory test results: beta-hydroxybutyrate daily, antiepileptic drug levels every other day, and glucose every 4 hours. Lipid levels and a liver panel are checked weekly.

Answer: A ketogenic enteral formula can be considered in refractory seizure disorder and should be monitored for safety and efficacy after initiation.

Rationale: Although the mechanism by which seizures are controlled with the ketogenic diet is largely unknown, there are several theories. One common theory suggests that the increase in ketones and decrease in glucose levels in the brain increases γ -aminobutyric acid uptake, which then increases adenosine-mediated neuronal inhibition as well as activity of adenosine triphosphate (ATP)–sensitive potassium channels, thereby decreasing the firing of neurons as well as the excitability during seizures.¹⁸⁸

Commonly used in children with well-documented success, the ketogenic diet has been emerging as an effective therapy for intractable seizures in adults; however, data are scarce on its use in the adult population.^{172–176} The ketogenic diet is not commonly used in adults because of the difficulty of maintaining the 4:1 ratio of fat to protein and carbohydrate.^{190,192,194} In addition, the diet is deficient in protein, and weight loss is common.^{187,195}

The 4:1 ratio of fat to protein and carbohydrate is difficult to maintain, in part because many medications contain carbohydrates as fillers or suspensions (see Table 22-4). Prior to starting the patient on the diet, the medical team needs to strictly control dextrose-containing medications (including topical medications) and items (such as mouthwash) that provide carbohydrates. Administering additional carbohydrates may prevent ketosis.

Monitoring of laboratory test values is important to ensure that ketosis is achieved; the most accurate data are beta-hydroxybutyrate levels (as opposed to urine levels of ketones).¹⁹⁶ Monitoring laboratory values on a regular basis also ensures that the patient does not have emerging problems such as hepatic steatosis, pancreatitis, or critically low blood glucose levels.^{196–198} Lower glucose levels should be tolerated while the patient is in ketosis. However, if glucose levels are less than 50 mg/dL, the patient should be given either 15 mL apple juice via the feeding tube or 50 mL of intravenous 5% dextrose in water at 100 mL/h. Lipid levels and a liver panel should be checked weekly. If triglyceride and

cholesterol levels are above normal, the dietitian and medical team should reevaluate the safety of a high-fat diet to consider the patient's cardiac status and pancreatitis risk.

Parkinson's Disease

Information regarding macro- and micronutrient requirements in Parkinson's disease is limited. Several factors affect the nutrition status of patients with Parkinson's disease, and weight fluctuations are common in the population.¹⁹⁹ In the beginning stages of the disease, body weight increases, likely due to a decrease in motor function. As the disease progresses, weight loss occurs. It is theorized that the metabolic rate increases because of worsening rigidity and dyskinesia.¹⁹⁹ In addition to increased energy needs, individuals with Parkinson's disease may experience dysphagia, which can further impair nutrition status.²⁰⁰ EN via a nasogastric tube is recommended for short-term nutrition support if the patient cannot meet nutrition needs by oral diet alone; PEG tubes are recommended when long-term EN is required.²⁰⁰

Common micronutrient deficiencies in Parkinson's disease have not been identified. Therefore, recommendations regarding supplementation cannot be made. One study suggested that vitamin D may be neuroprotective in Parkinson's disease, but the investigators did not make recommendations regarding vitamin D supplementation.¹⁹⁹

The interaction between carbidopa/levodopa drug therapy and protein intake is well documented. The medication and protein compete for transport into the small intestine and blood-brain barrier.¹⁹⁹ Fluctuations in absorption of levodopa can affect motor function, and this drug therapy has been associated with decreased intake of protein.¹⁹⁹

Constipation is common in patients with Parkinson's disease, and fiber and fluid intake are encouraged.¹⁹⁹ Higher levodopa requirements have been associated with increased constipation, and diet management is recommended.¹⁹⁹

Other Neurologic Conditions

Other neurologic diseases, such as multiple sclerosis, muscular dystrophy, Alzheimer's disease, and dementia, can affect nutrition status. The literature on nutrient needs, micronutrient deficiencies, and unique metabolic issues in these conditions is limited. More research is clearly needed to determine how to optimize nutrition status and establish guidelines for medical nutrition therapy specific to these disease states.

Patients with chronic neurologic conditions may be more prone to malnutrition because of declining cognition, dysphagia, motor difficulties, and other comorbidities common to advancing neurologic diseases. Nutrition therapy is paramount to improving outcomes and, in some cases, decreasing mortality. See Chapter 36 for more information on dementia.