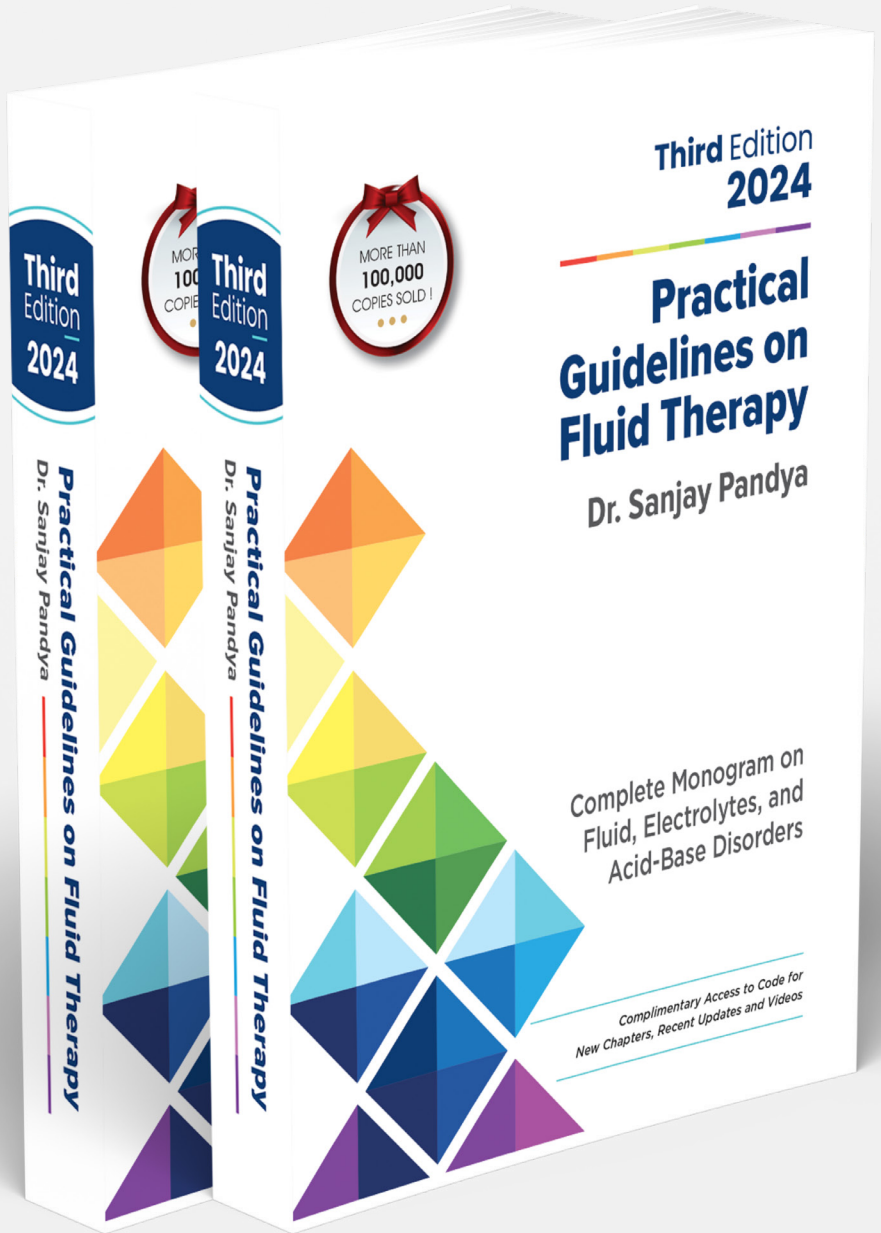
fluid therapy.org

Chapter 56:

Parenteral Nutrition in Specific Diseases



To get a copy of the book, visit: **www.fluidtherapy.org**

Fluid therapy.org

Table of Contents

56 Parenteral Nutrition in Specific Diseases

In specific diseases, individuals have nutritional needs that differ from the usual guidelines, necessitating a personalized nutritional strategy. These conditions require a tailored nutritional approach to meet their distinct requirements. This chapter will discuss the unique nutritional considerations, goals, indications, timing for initiating parenteral nutrition, nutritional requirements, and management of several common disorders.

ACUTE KIDNEY INJURY (AKI)

Nutritional considerations

In acute kidney injury, the rapid decline in kidney function not only leads to water, electrolyte, and acid-base disturbances but also affects carbohydrate, protein, and lipid metabolism and significantly affects nutrition. In AKI, excessive protein catabolism and inadequate intake of nutrition lead to protein-energy wasting (PEW) and malnutrition.

Malnutrition is common in hospitalized patients with AKI, is a poor prognostic marker, and is a significant predictor of morbidity and mortality in AKI [1–4]. In addition, patients with AKI given low calories and amino acids are associated with higher hospital mortality [5]. So, do not restrict protein intake in AKI patients to avoid or delay the initiation of dialysis [6, 7].

Goal, indications, and timing for initiation of parenteral nutrition (PN)

The general goals of nutrition support are to prevent malnutrition, maintain nutritional status, and limit the complications of AKI by providing adequate amounts of energy, protein, and nutrients.

AKI patients with mild catabolism can be fed orally. Moderate to severely catabolic patients with AKI need nutritional support, and enteral nutrition is the preferred route in such patients. However, total or supplementary PN has indicated if enteral nutrition is inadequate or cannot be given in patients with significant gastrointestinal (GI) dysfunction [8].

When to initiate PN in patients with AKI is an important question to be answered. Early PN may delay recovery in AKI and prolong the duration of renal replacement therapy due to substantial catabolism of the extra amino acids leading to higher levels of plasma urea and, therefore, should be avoided [9].

Compared with early initiation, late initiation of PN is associated with rapid recovery and lesser complications in critically ill adults [10]. Recent ESPEN guidelines (2019) recommended starting PN within three to seven days and providing half of the predicted or measured energy need in the beginning [11].

Nutritional requirements and management

Nutritional requirements of AKI depend on various factors such as underlying disease, associated comorbidities, the need for renal replacement therapy (RRT), including its type and frequency, and pre-existing nutritional status, as summarized in Table 56.1.

1. AKI treated conservatively (non-dialytic therapy)

- **Energy requirements:** It varies as per the clinical status of patients with AKI.

  Energy required for uncomplicated AKI is in any stage is 20–30 kcal/kg/day, which is similar to that required by a normal adult individual [7, 12].

  Energy requirement increases (about 25 to 35 kcal/kg/day) in critically ill patients with AKI (e.g., severe sepsis, respiratory failure, burns, and multi-organ failure) [13, 14] and during continuous renal replacement therapy (CRRT) [15].

  Providing higher calories does not improve patients' outcomes in AKI [16]. In AKI patients, indirect calorimetry is the standard and clinically recommended method to calculate energy requirements which helps to avoid overfeeding.

Table 56.1 Guidelines for nutritional requirements in acute kidney injury			
Nutritional requirements	**ESPEN 2006**	**KDIGO 2012**	**ASPEN 2016**
Energy	20–30 kcal/kg/d	20–30 kcal/kg/d	25–30 kcal/kg/d
Protein			
Noncatabolic AKI without dialysis	0.6–0.8 gm/kg, max. 1.0 gm/kg	0.8–1.0 gm/kg	1.2–2 gm/kg
RRT, in hypercatabolism	1.0–1.5 gm/kg	1.0–1.5 gm/kg for RRT, up to 1.7 gm/kg for CRRT	Additional 0.2 gm/kg up to 2.5 gm/kg
Carbohydrates	3–5 gm/kg (max. 7 gm/kg)	-	-
Lipid	0.8–1.2 gm/kg (max. 1.5 gm/kg)	-	-

- **Protein requirements:** Protein requirements in AKI needs due attention as it is variable based on the condition of the individual patient (Table 56.1). Protein requirements recommended for patients of AKI, not on dialysis is 0.8–1.0 gm/kg/day for stable, non-catabolic patients (KDIGO 2012) and 1.2–2 gm/kg for critical ICU patients (ASPEN 2016) [6, 7]. Avoid supplementation of the greater amount of protein in AKI because retention of nitrogenous waste will aggravate uremic complications and can also contribute to acidosis [7].
- **Non-protein caloric supplements:** In AKI receiving PN, carbohydrates, and lipids represent about 65–70% (3 to 5 gm/kg/d) and 30–35% (0.8 to 1.0 gm/kg/d) of the calorie intake of total non-protein energy supply respectively [7, 17].
- **Fluid and electrolytes requirements:** Adjust/restrict fluid intake as per the urine output to avoid volume overload in oliguric patients. Most of oliguric patients also need sodium restriction. Maximally concentrated PN solutions are infused through a central line in oliguric patients. Avoid hyperkalemia, hypermagnesemia, and hyperphosphatemia by restricting potassium, magnesium, and phosphorus in PN.

2. AKI treated with renal replacement therapy

A large amount of amino acids is lost into the effluent fluid during RRT, and its variable depending on the type of modality (i.e., the approximate amount of amino acid lost is about 3–6 gm during conventional hemodialysis, 7–10 gm during sustained low-efficiency dialysis (SLED), and 14–22 gm per session during continuous venovenous hemofiltration (CVVH) respectively [18]. To compensate for the protein loss, protein replacement KDIGO recommended are 1.0–1.5 gm/kg/d for AKI on intermittent RRT and up to 1.7 gm/kg/d in patients on continuous renal replacement therapy (CRRT) [7]. To replace a significant loss of amino acid in CRRT, it is recommended to increase protein intake to a range of 1.5–2.5 gm/kg/day [6, 14, 19].

BURNS

Nutritional considerations

Malnutrition in patients with burns carries a high risk of complications such as infection and delayed wound healing and therefore is very important in managing moderate-to-severe burn injury.

Important causes of malnutrition in burns are:

- Loss of protein and micronutrients as the skin barrier is lost.
- Increased energy expenditure to overcome heat loss through the exposed surface and to maintain body temperature.
- Persistent and prolonged post-burn hypermetabolic state and increased catabolism.

Feeding route: In burn patients, enteral nutrition (EN) is recommended over PN because of the advantages of early EN, such as protection of the gastrointestinal tract, improved nutrient adequacy, reduction in rates of complications, infection, length of hospital stay, cost, morbidity, and mortality [20, 21]. EN is preferred, and PN is not recommended routinely in burns because of adverse effects like overfeeding, impaired immunity, liver failure, and higher mortality [22]. PN is administered in burn patients only when EN is not feasible, not tolerated, or inadequate to meet with desired total nutrient requirements [6].

Nutritional requirements and management

Energy requirements: In patients with burns, nutritional support is provided to meet increased energy requirements due to the hypermetabolic state without causing overfeeding [23]. Indirect calorimetry is the standard and preferred method to determine energy requirements in burns [6]. However, different equations used to determine energy requirements in burns are less reliable because they overestimate or underestimate caloric requirements [24]. When indirect calorimetry is not available or feasible, alternatively Toronto equation is recommended in adults [20].

Protein requirement: Protein requirement is significantly higher in burns because of the need for protein for wound healing, immune function, to replace ongoing losses, and to reduce protein catabolism [23]. ESPEN (2013) and ASPEN (2016) guidelines recommend 1.5 to 2 gm protein/kg/day in adults [6, 20].

Carbohydrate requirement and glycaemic control: Administer carbohydrates to provide up to 60% of total energy intake from nutrition and non-nutritional sources [20]. However, carbohydrate administration carries the risk of hyperglycemia, and poor glucose control adversely affects outcomes in burns [25]. So, while infusing carbohydrates, monitor blood glucose levels closely, and keep glucose levels under 144 mg/dL (and over 81 mg/dL), preferably by continuous intravenous insulin infusion to achieve tight glycemic control.

Lipid requirement: Administer lipids to provide <35% of total energy intake from fat and monitor total fat delivery [20].

As metabolic demands are high in patients with severe burns, administration of PN via central venous access is preferred.

Glutamine and micronutrients requirement: Supplementation of 0.3 gm/kg/day glutamine is beneficial. Patients with major burns have increased micronutrient requirements due to hypermetabolism, wound healing requirements, and cutaneous exudative losses and need an early supplementation with supra-nutritional amounts of zinc, copper, selenium, and vitamin B1, C, D, and E to prevent deficiency-related complications [20].

CANCER

Cancer-related malnutrition (CRM), weight loss, and cachexia occur in 30 to 80 percent of cancer patients, which contribute to excess morbidity and mortality [26, 27].

Malnutrition reduces the benefit of cancer therapy, increases chemotherapy-related toxicity, leads to poor quality of life, and reduces patient survival.

Why malnutrition occurs in cancer patients?

Malignancy per se or treatment of the malignancy (such as chemotherapy, radiotherapy, or surgical treatment) can lead to loss of test, decreased appetite, nausea, vomiting or diarrhea, oral lesions, severe mucositis, and GI complications such as dysphagia, ileus, intestinal obstruction, malabsorption, short bowel syndrome, and fistulae, which can lead to malnutrition [28].

Nutritional support reduces symptoms, improves the quality of life, reduces weight loss, prevents catabolism, and improves outcomes in cancer patients.

Indications of PN [27, 29, 30]

- PN is not recommended routinely in well-nourished cancer patients because of the lack of advantages and associated harmful effects.
- Access to the digestive tract is not possible for a prolonged period due to GI complications such as perforation, intestinal obstruction, high-output entero-cutaneous fistulas, or chylothorax.
- Chemotherapy or radiotherapy-induced GI toxicity limiting oral/enteral intake for more than 1–2 weeks in cancer patients.
- As anticancer therapy is ineffective in rapidly progressive malignant diseases and terminal stages of malignancy, PN is unlikely to benefit such patients.
- In patients receiving hematopoietic stem cell transplantation, PN is recommended if oral/EN is limited due to severe mucositis, ileus, or intractable vomiting.

Nutritional requirements

The total daily energy expenditure is about 20–25 kcal/kg/day for bedridden cancer patients and 25–30 kcal/kg/day for ambulatory cancer patients [27, 29]. Recommended protein intake is >1 gm/kg/day and, preferably up to 1.5 gm/kg/day [27].

The proportion of carbohydrates and lipids is roughly 40–50% or less and up to 50% of non-protein energy requirements, respectively [31]. The requirement of lipids is about 0.5–1.5 gm/kg/day (up to a maximum of 2 gm/kg/d).

Higher fat to carbohydrate ratio to provide non-protein energy is recommended in weight-losing, cachectic cancer patients with insulin resistance because of the advantages of lipids, such as increased energy density and ability to reduce the glycemic load [27].

CARDIAC DISEASE

Patients with chronic heart failure (CHF) carry the risk of malnutrition due to decreased energy intake, increased energy expenditure and impaired anabolism, and high mortality in patients with CHF with cardiac cachexia [32]. Reduced bowel perfusion due to decreased cardiac function can cause edema of the bowel wall leading to malabsorption [32].

In cardiac patients, oral supplementation and enteral nutrition are preferred, and PN is needed in very few patients who cannot take adequate oral or enteral nutrition.

Because of the potential risk of volume overload and hyponatremia, PN should be used cautiously, preferably using concentrated PN solutions. Lipid emulsion can provide greater calories (9 kcal/gm) with a smaller volume.

CRITICAL ILLNESS

Critical illness refers to seriously ill medical or surgical conditions that need intensive care and is associated with a greater risk of infection, longer ICU stays, and higher mortality. Malnutrition is quite common in critical illness (occurs in about 38% to 78% of patients) and increases morbidity, mortality, and hospital-related cost [33]. Malnutrition in critical illness usually occurs due to multiple causes, such as increased energy expenditure, marked catabolism, decreased food intake for a prolonged period due to anorexia, and different medical or surgical gastrointestinal disorders.

In critical illness, adequate nutrition is important because malnutrition is associated with impaired clinical outcome, starvation or underfeeding leads to increased morbidity and mortality, and timely optimum nutrition decrease hospital stay and morbidity [34–36].

Metabolic changes: Depending on the duration of critical illness, it is divided into three stages: acute early phase, acute late phase, and post-acute late phase [11]. Different metabolic changes according to these stages help in planning the appropriate nutritional therapy considering varying needs. In the acute early phase, catabolism-induced increased endogenous generation of energy helps to meet the demand of the body in critically ill patients, and therefore, early use of PN with the provision of standard energy requirements is likely to cause overfeeding [37]. Characteristics of metabolism at the different time frames in critical illness as summarized in Table 56.2 [11].

Enteral nutrition vs. parenteral nutrition

In critically ill patients, EN is preferred and recommended over PN because of its safety and various advantages by all recent international guidelines [6, 11, 38]. In the CALORIES trial, PN is found to be as safe as EN in a critically ill patient when the dose of PN is hypocaloric, which is equivalent to EN dose [39]. So, the advantages of EN may be due to differences in the intake of calories rather than the route; therefore, using PN in an appropriate dose is as safe as EN [40].

When to provide nutrition in critical illness?

The timing of the initiation of PN is important and controversial critically ill patients. No benefit or harm was documented with early nutrition in the recent TARGET Trial (2018) [41, 42]. In the largest nutrition EPaNIC trial (2011), the potential harm with early PN and benefits such as enhanced recovery, fewer complications, and reduced healthcare costs were demonstrated with the late initiation PN [10]. So, in adequately nourished crit-

Table 56.2 Metabolic characteristic of critical illness

Stage	ICU days	Metabolism	Characteristic
Acute phase early period	1–2	Catabolism	Metabolic instability and severe increase in catabolism
Acute phase late period	3–7	Catabolism	Significant muscle wasting and stabilization of the metabolic disturbances
Post-acute late phase	After day 7	Anabolism	Improvement and rehabilitation
		Catabolism	Chronicity with persistent inflammatory/catabolic state and prolonged hospitalization.

ically ill patients with low nutrition risk, if PN is indicated, it should be administered late because of the harmful effects of early PN and the benefits of the late initiation PN. Recent European guidelines recommend initiation of PN between ICU days 3 and 7 (ESPEN 2019), while American guidelines recommend initiation of PN after 7 days (ASPEN/SCCM 2016) [6, 11].

Indications of PN

Adequate nutrition is beneficial during and after the ICU stay in critical illness. Therefore, in critically ill patients, exclusive or supplemental PN is indicated when oral/EN is contraindicated or fails to achieve nutritional targets, which prevents underfeeding associated risks and poor outcomes:

- Critically ill patients who are well-nourished and have a low risk for malnutrition generally do not need exclusive PN in the first seven days of an ICU stay [6, 43].
- In critical patients with high nutrition risk or severe malnutrition, initiate exclusive PN at the earliest following ICU admission if EN is not feasible [6].
- Supplemental PN: If oral/EN fails to meet >60% of energy and protein requirements after seven to ten days, the use of supplemental PN is recommended in patients with a low or high nutritional risk [6]. Supplemental PN is a step-up approach that helps to provide timely and optimal nutrition support during critical illness.

Nutritional requirements and management

How to initiate PN in critical illness?

Current literature is against the traditional practice of aggressive nutrition in the early stages of critical illness [44]. Both European and American guidelines recommend a strategy to provide hypocaloric PN (≤20 kcal/kg/d or 70–80% of estimated energy requirements) with an adequate protein supplementation (≥1.2 gm protein/kg/d) in the first week of hospitalization in the ICU to avoid overfeeding [6, 11]. The strategy to provide hypocaloric PN reduces peripheral insulin resistance and risk of hyperglycemia and improves glycemic control with resultant increases in the safety of PN. After the patient stabilizes, the dose of PN may be increased gradually to achieve 100% of the estimated energy requirements [6].

The nutritional requirements of critical and stable patients are summarized in Table 56.3 [6, 11, 12].

Energy expenditure: Indirect calorimetry is the preferred method to calculate caloric needs [6, 11]. The approximate total energy expenditure in critically ill patients is about 20 to 30 kcal/kg/day [12]. Initial administration of 70–80% of the measured energy expenditure is beneficial, whereas higher or lower energy intakes are both harmful [45–47]. Critical patients with low serum phosphorus levels (less than 0.65 mmol/L or 2 mg/dL) are prone to develop refeeding syndrome. So in such patients, restrict calorie intake to 50% of the calculated energy needs for 2 to 3 days to prevent the refeeding syndrome [48].

Protein requirements: In the acute phase of critical illness, increased catabolism causes loss of protein and muscle wasting [49, 50], and therefore requirements of protein increase considerably with illness severity. Inadequate protein supplementation may be harmful, and supplementation of protein intake may be beneficial and found to reduce the mortality in critically ill patients in recent literature [45, 51–53].

Table 56.3 Nutritional requirements in critical and stable patients		
	Critically ill patients	**Stable patients**
Total calories	20 to 30 kcal/kg/d	20 to 30 kcal/kg/d
Protein	1.3 (1.2–2.0) gm/kg/d	0.8 to 1.5 gm/kg/d
Carbohydrate	Not >5 mg/kg/min	4–5 mg/kg/min
Lipid	Less than 1.5 gm/kg/d (100 gm/wk)	1 gm/kg/d
Fluid	Minimum needed to deliver adequate macronutrients	30 to 40 mL/kg/d

As per current recommendations, a higher amount of protein should be provided to critically ill patients (i.e., up to 1.3 gm/kg/day as per ESPEN guidelines (2019) and 1.2–2.0 gm/kg/day as per ASPEN/SCCM guideline (2016) [6, 11]. Administration of protein in a low dose initially (<0.8 gm/kg/day before day 3) and subsequently gradually increasing its dose (>0.8 gm/kg/d after day 3) is beneficial and reduces mortality [54].

Combining exercise with calorie and protein supplementation is very important because it helps to maintain muscle mass and function, reduces protein catabolism, and improves outcomes [11, 55, 56].

Carbohydrate requirements: Carbohydrate is the preferred source of energy in the early phase of critically ill patients. The minimum amount of carbohydrate requirement recommended in ICU patients by 2003 ESPEN guidelines was 2 gm/kg of glucose per day [34] and 1–2 gm/kg/day by the German Association for Nutritional Medicine [57]. But in current literature, the lower limit is removed due to a lack of evidence, and 2019 ESPEN guidelines recommend that in ICU patients receiving PN, the amount of glucose should not exceed 5 mg/kg/min [11].

Avoid Hyperglycemia in critically ill patients because it is harmful and is associated with an increased risk of complications and higher mortality. In critically ill patients, the recommended target blood glucose ranges from 140 or 150 to 180 mg/dL [6, 58]. The use of insulin infusion is recommended for achieving normoglycaemia because controlling blood sugar decreases mortality in critically ill patients. Insulin infusion is used when blood glucose is >150 mg/dL to maintain it below 180 mg/dL [59].

Lipid emulsions: For critically ill patients who are hemodynamically stable, lipid emulsion is an essential part of PN, as it provides a dense source of non-protein calories and essential fatty acids [11].

Requirements: Administration of intravenous lipid emulsions can be initiated safely at a rate of 0.7 gm/kg/day, and the total dose of lipid should not exceed 1.5 gm lipids/kg/day or a maximum of 100 gm/week and should generally provide about 30% of total calories [6, 11, 60, 61].

Selection of lipid emulsions: Lipid emulsions containing soybean oil are the mainstay and the first-generation lipids for parenteral nutrition. Alternative lipid emulsions, such as Generation 2 (combining soybean oil with medium-chain triglycerides), Generation 3 (using olive oil), and Generation 4 (using fish oil) lipid emulsions, have been developed to decrease the harmful effects of the omega-6-rich linoleic acid content and to lower the ratio of omega-6 to omega-3 fatty acids [62]. Because of the potential risks associated with the use of pure soybean oil emulsions in critically ill

patients, 2016 SCCM/ASPEN guidelines recommend against its use during the first week of starting PN [6]. On the contrary, omega-3 fatty acid enriched fish oil containing PN is beneficial and reduces the risk of infection and sepsis, and shortens the length of stay in both ICU and hospital [63].

So current literature recommends the use of fish-oil containing lipid emulsions as part of PN in surgical and high-risk critically ill adult patients (e.g., sepsis, acute respiratory distress syndrome (ARDS), persistent inflammation catabolism syndrome [PICS]), although evidence to support its use in non-surgical patients is not sufficient [6, 11, 64, 65]. Because of clinical benefits over the standard lipid emulsions, provide 0.1–0.2 gm/kg/day fish oil containing lipid emulsions [rich in EPA (eicosapentaenoic acid) + DHA (docosahexaenoic acid)] in patients receiving PN [11].

Monitoring: While administering lipid emulsions, measure serum triglyceride concentrations at baseline, monitor it regularly, and adjust the dose of lipid emulsions to maintain triglyceride levels below 400 mg/dL (4.5 mmol/L) [64].

Micronutrients and glutamine

Vitamins and trace elements (micronutrients) are essential components of PN. As commercially available PN formulations do not contain vitamins and trace elements, their separate administration is needed. In addition, a high dose of micronutrients may improve the outcomes of critically ill patients [66].

Parenteral glutamine supplementation is not recommended in critically ill, unstable, and complex ICU patients and patients with multi-organ failure, especially with liver and renal failure in recent guidelines (Canadian guidelines 2015, ASPEN guidelines 2016, ESPEN guideline 2019) [6, 11, 67].

GASTROINTESTINAL FISTULAE

Gastrointestinal (GI) fistulas divert intestinal contents, most commonly to the skin (cutaneous, gastrointestinal fistula). Common causes of GI fistula are crohn's disease, injury to the bowel, bowel surgery, radiation injury, abscess, and foreign body penetration.

High output GI fistulas (loss greater than 500 ml of fluid in 24 hours) might cause massive loss of fluid, electrolytes, proteins, vitamins, and trace minerals resulting in complications like severe dehydration, fluid, electrolytes, acid-base abnormalities, and malnutrition (which occurs in about 55–90% of patients) [68, 69]. In addition to these abnormalities, profound nutrient depletion and sepsis are leading causes of death in patients with high-output GI fistulas [70].

Nutritional support

The provision of optimum nutrition is necessary because it significantly improves clinical outcomes by accelerating the spontaneous healing rate, enhancing the closer of the fistula, and reducing the mortality rate in patients with high-output GI fistulas [71, 72]. Therefore, PN is started in patients with high output fistula after initial fluids and electrolytes resuscitation and control of sepsis.

Indication: PN has a supportive role, and its indications in patients with GI fistula are [71, 73, 74]:

- High-output fistula (e.g., >500 mL/day), presence of distal intestinal obstruction, or length of intestinal before the fistula less than 75 cm because these patients cannot tolerate oral or EN.
- When oral or EN fails to provide adequate nutrition beyond 7 days.

- Supplemental PN is provided when EN alone cannot achieve the nutritional goal to meet their metabolic needs.

PN improves nutritional status by providing adequate nutrition, allows time to correct sepsis and thereby prepare them for reconstructive surgery, and helps to postpone extremely hazardous emergency surgical intervention in severely ill patients with GI fistulas.

Nutritional requirements and management: Patients with high-output fistula requires 25 to 35 kcal/kg per day of total caloric intake and 1.5–2.0 gm/kg/d of protein [75]. As protein loss in the effluent of high output fistula can be as high as 75 gm/day, ASPEN-FELANPE clinical guidelines recommend more protein (up to 2.5 gm/kg/d) supplementation in adult patients with high output fistula [73].

Lipids are usually given roughly 20–30% of calories. The use of lipid emulsion containing omega-3 fatty acid-enriched fish oil in PN is beneficial because it is a calorically dense nutrient and has an immune-enhancing effect that reduces the risk of sepsis and shortens the duration of hospitalization [63].

Vitamins and trace elements deficiency is common in malnourished patients, and its supplementation is recommended. The recommended vitamin C and zinc dose is about ten times the daily allowance, while the dose of other vitamins is two times normal [76].

INFLAMMATORY BOWEL DISEASE (IBD)

Inflammatory bowel diseases are chronic, relapsing, and debilitating inflammatory disorders of the gastrointestinal tract, and their most common causes are crohn's disease (CD) and ulcerative colitis (UC).

Malnutrition occurs in about 6% to 16% of patients with IBD [77, 78].

The etiology of malnutrition in IBD is multifactorial, results from decreased food intake, poor digestion, malabsorption, increased losses of nutrients, increased energy requirements, a short length of the intestine due to resection, and drug or surgery-related factors [79, 80].

Adequate correction of malnutrition is essential in patients with IBD because it worsens the prognosis and adversely affects the quality of life by increasing complication rates and mortality [81, 82].

PN does not increase the remission rate or decrease the need for surgery in patients with IBD. Therefore, PN and bowel rest should not be used routinely as primary therapies for IBD. PN is less effective than steroid therapy in the treatment of CD. Correction of dehydration and replacement of various micronutrients are more critical than bowel rest alone.

Indications of PN

- EN is preferred over the PN, and PN is indicated only in selected patients with IBD [81–84].
- If oral or EN is insufficient to deliver nutrition targets (cannot supply >60% of energy needs) in patients with crohn's disease due to GI tract dysfunction or short bowel.
- If oral or EN is not possible due to severe vomiting or diarrhea and absence of access.
- If oral or EN is contraindicated due to paralytic ileus, an obstructed bowel, intestinal ischemia, or severe shock.
- If the patient develops complications such as an anastomotic leak or a high output intestinal fistula.
- In the perioperative period, provide PN if oral or EN cannot be initiated within 7 days.
- In the postoperative period, provide PN if oral or EN cannot be initiated within 7 days.

LIVER DISEASE

The liver is labeled a "workhorse" because it performs multiple complex tasks such as metabolism, alteration, synthesis, storage of various nutrients, and detoxifying different toxic substances.

Malnutrition is commonly seen in patients with liver disease, and its prevalence is about 20% in compensated cirrhosis and as high as 50%–90% in advanced cirrhosis [85, 86].

Important causes of malnutrition are excessive use of alcohol, decreased food intake, impaired gastric emptying, impaired digestion, malabsorption, altered metabolism, increased resting energy expenditure, insufficient nutrient storage and synthesis, and abnormal nutrient losses [86, 87].

Early detection of malnutrition in liver disease is important because it adversely affects outcomes by causing loss of muscle mass (sarcopenia), increased rate of complications (encephalopathy, variceal bleeding, and infection), a longer stay in the hospital, and higher mortality [88–91]. Early diagnosis and proper treatment of malnutrition, ascites, and hyponatremia can reduce morbidity and mortality in patients with liver disease.

Indications of PN

Selective use of PN is beneficial in patients with hepatic failure as it reduces complication rates, duration of mechanical ventilation, and stay in ICU [92].

Common indications of PN are [92–95]:

- When oral or EN are inadequate or contraindicated, PN is used as second-line treatment according to the current recommendation for non-cirrhotic patients.
- PN is beneficial in patients with poor oral intake for a prolonged period and problems like hepatic encephalopathy, gastrointestinal bleeding, and impaired gut motility or ileus.
- In patients with moderate or severe malnutrition, prompt administration of PN is recommended, as in other critically ill patients.
- To provide early postoperative nutrition after liver transplantation and surgery when oral nutrition or EN is not feasible. Postoperative PN helps to reduce rates of complication, length of mechanical ventilation, and ICU stay.
- Considered PN in the presence of problems like unprotected airways, compromised cough and swallow reflexes, and hepatic encephalopathy.

Nutritional requirements and management

Nutritional requirements in patients with liver diseases vary depending upon the type of liver disease, the severity of illness, malnutrition, and associated complications.

Energy requirements

Energy expenditure usually increases in patients with acute liver failure, alcoholic steatohepatitis, and cirrhosis, but it is normal in non-alcoholic fatty liver disease (NAFLD). The basal metabolic rate should be calculated using the actual body weight for patients with cirrhosis of the liver without ascites, but for patients with cirrhosis of the liver with ascites, use the ideal body weight for the calculation [6, 94].

Energy requirements increase in cirrhotic patients with acute complications, refractory ascites, malnutrition, or hepatic encephalopathy, but not for overweight or obese patients (as summarized in Table 56.4) [6, 92, 94, 96, 97].

In cirrhotic patients, carbohydrates should provide 50–60%, and lipids should

provide about 40–50% of non-protein energy requirements [93].

Protein requirements

Providing optimum protein supplementation to the cirrhotic patient is the most important and challenging part of nutrition. Protein restriction to prevent the development of hepatic encephalopathy (HE) is one of the most common misconceptions. Restriction of protein should be avoided because it increases protein catabolism, and on the contrary, high protein supplement actually improves mental status and does not precipitate or worsen HE [98–100].

The requirement for protein increases in malnourished and/or sarcopenic cirrhotic patients, patients requiring frequent or large-volume paracentesis, and obese cirrhotic patients for preserving lean body mass, as summarized in Table 56.5 [6, 92, 94].

Vitamins and micronutrients

Vitamins and micronutrient deficiencies are frequently seen in patients with liver diseases, especially those with alcoholic cirrhosis. Such patients require the supplementation of vitamins (both fat and water-soluble) and micronutrients. In addition, increased prothrombin time (PT) is frequently encountered in patients with liver diseases, and vitamin K is routinely supplemented to correct PT; however, evidence regarding its efficacy is limited [101, 102].

Zinc deficit is common in patients with cirrhosis of the liver, and evidence of the benefits of zinc supplementation in hepatic encephalopathy is growing [103–107].

Fluid and salt requirements

Cirrhosis affects the patient's ability to handle salt and water and may cause ascites and dilutional hyponatremia. Ascites is the common complication of cirrhosis of the liver, and in patients with severe anasarca and ascites, salt and water restriction may be necessary. Hyponatremia is prevalent in patients with ascites due to cirrhosis and is associated with higher morbidity and mortality [108].

Salt restriction: Dietary sodium restriction is the first-line therapy in ascites, and recent guidelines recommend intake of about 80–113 mEq sodium or 5–6.5 gm of salt per day [92, 109]. While prescribing a low-salt, unpalatable diet, it is essential to consider the trade-off between reducing caloric intake, which can lead to a risk of malnutrition from decreased food intake, and its moderate advantage in reducing ascites [94, 110]. Therefore, salt restriction is not recommended in patients with cirrhosis in the absence of ascites.

Fluid restriction: Restriction of fluid to 1 to 1.5 L per day should be considered only in patients with clinical hypervolemia with severe hyponatremia (serum sodium <125 mmol/L) [109]. Fluid restriction

Table 56.4 Energy requirements in liver diseases

Requirements	Clinical conditions
25–30 kcal/kg/d	Compensated liver cirrhosis
30–35 kcal/kg/d	Acute liver failure, alcoholic hepatitis, decompensated cirrhosis (in nonobese individuals), cirrhotic with malnutrition, hepatic encephalopathy, preoperatively and postoperative cirrhotic patients
25 kcal/kg/d	Obese cirrhotic patient
35–40 kcal/kg/d	Critically ill cirrhotic patients

Table 56.5 Protein requirements in liver diseases	
Requirements	**Clinical conditions**
1.2 gm/kg/d	Non-malnourished compensated liver cirrhosis
1.5 gm/kg/d	Decompensated cirrhosis (in nonobese individuals), malnourished and/or sarcopenic cirrhotic patients
1.2–1.5 gm/kg/d	Preoperatively and postoperative cirrhotic patients, hepatic encephalopathy
1.5–2 gm/kg/d	High volume recurrent ascites with sarcopenia
2.0–2.5 gm/kg/d	Obese cirrhotic patient
>1.2 gm/kg/d	Critically ill cirrhotic patients

is not recommended in hypovolemic hyponatremia and mild to moderate hyponatremia.

PANCREATITIS

Nutritional considerations

Acute pancreatitis (AP) is severe in about 20% of patients, and severe acute pancreatitis increases the mortality rate by 19–30% [111]. Severe acute pancreatitis is a hypercatabolism state leading to sustained protein catabolism and increased energy requirements with resultant nutritional risk [112]. Timely adequate nutrition plays a key role in the management of severe acute pancreatitis.

The concept of "Pancreatic Rest" is changing: Formerly, in the early stages of severe acute pancreatitis, patients were kept nil by mouth and given PN to provide rest to the pancreas. The previously popular concept of "Pancreatic Rest" was based on the presumption that oral or enteral feeding could stimulate pancreatic enzyme secretion, causing autodigestion of the pancreas and surrounding tissues and worsening pancreatitis.

The rationale for discarding "Pancreatic Rest" and changing to EN in the early phases of severe acute pancreatitis are:

- The lack of oral or enteral nutrition leads to a loss of intestinal mucosal barrier function and increased bacterial translocation, resulting in an increased risk of complications such as pancreatic infection and necrosis [113].
- During acute pancreatitis, the secretion of pancreatic enzymes decreases significantly, with the most severe cases having the lowest secretion. As a result, even if EN is taken, it does not increase secretion because it is already reduced, making EN not harmful in severe acute pancreatitis [114, 115].
- The beneficial effects of oral/EN are improvement in nutritional status, stimulation of intestinal motility, increase in splanchnic blood flow, and maintenance of gut integrity which inhibits bacterial translocation, reduction of pancreatic infection, decrease in local and systemic inflammation risk, and reduced mortality [116–118].
- Use of parenteral nutrition for bowel rest has a potential risk for hyperglycemia, electrolyte imbalances, catheter-related infections, and sepsis, and is more expensive than EN [119, 120].

To conclude, the concept of "Pancreatic Rest" is outdated, detrimental, and should be abandoned [117, 121–123].

Enteral vs. parenteral nutrition

In the early phases of severe acute pancreatitis, EN is safer, more effective, and is preferred compared with parenteral nutrition according to different studies [124–128], current reviews [113, 116–118], and recent guidelines [6, 112, 123, 129–133].

Compared to PN, oral or EN has demonstrated multiple benefits such as decreased infectious complications, risk of complications, mean length of hospital stay, rate of multiple organ failure, and mortality rate in patients of severe acute pancreatitis in several studies [124–128, 134, 135].

Timing of initiation of EN: The early EN (i.e., initiated within 72 hours [112, 132, 136], 48 hours [6, 125, 130, 135, 137–141], or 24 hours [123, 142, 143] had significant benefits over the delayed EN such as decrease complication rate, organ failure, mortality, length of stay in the hospital, and cost-effectiveness.

It is very important to start EN early in moderate to severe acute pancreatitis because the inability to provide EN for >72–96 hours carries the risk of the rapid deterioration of nutrition status and resultant complications such as increased mortality, frequency of infected necrosis, and length of stay in hospital [6, 138].

Route of nutritional support: The most effective route of nutritional support in acute pancreatitis is determined based on the severity of diseases, associated local and systemic complications, and nutritional status at the time of admission.

Oral feeding: Patients with mild acute pancreatitis should consume normal food intake as tolerated, and the use of EN or PN is not recommended [6]. Recent guidelines [AGA (2018), NICE (2018), and ESPEN (2020)] recommend early initiation of oral feeding in patients with mild acute pancreatitis instead of traditional 'nil-by-mouth' or delayed oral feeding (initiation after reduction of serum amylase and lipase levels, resolution of abdominal pain and bowel sounds become normal) [112, 123, 132].

Early oral feeding (within 24 hours) is safe, and well-tolerated, with no differences in adverse events compared to standard oral refeeding or EN, may shorten the length of hospital stay as well as costs, and help in rapid clinical improvement [144–147]. Oral feeding is usually started when abdominal pain, nausea, and vomiting decreases, the patient feels hungry and intestinal obstruction or ileus are excluded (it is not necessary to wait until abdominal pain resolves completely or serum lipase concentrations decline) [112, 122, 129, 148, 149]. If the patient is unable to take oral intake within 72 hours, EN should be initiated on day 4 [145].

Enteral nutrition (EN): EN is a cheaper, safer, and the most preferred modality for nutritional support in severe acute pancreatitis, where feeding is provided directly into the stomach via a nasogastric tube (NG) or post-pyloric region by a nasojejunal tube (NJ) [128]. If a patient with acute pancreatitis is unable to eat, providing nutrition by enteral feeding is beneficial and preferred over parenteral nutrition.

It is important to remember that enteral feeding can be administered safely and successfully even in the presence of complications such as pseudocysts, ascites, and/or fistulas [150, 151].

In severe acute pancreatitis with high intraabdominal pressure (IAP) and abdominal compartment syndrome having abdominal distension, paralytic ileus, and high gastric residual volume, EN may be initiated cautiously by using nasojejunal as a preferred route [112, 131]. Monitor the intraabdominal pressure and the

clinical condition continuously and closely in such patients. EN is initiated gently at a 10–20 mL/h rate via the nasojejunal route when intraabdominal pressure (IAP) is <15 mmHg, but IAP >15 mmHg may need temporary reduction or discontinuation of EN due to higher rates of feeding intolerance [112, 131, 152].

Because of physiological benefits, at least a small amount of EN may be administered supplementary to PN in patients with severe AP and open abdomen, if feasible [112].

Gastric vs. jejunal nutrition

Nasogastric feeding is a preferred route for EN because it is simpler, cheaper, easier to insert, requires less time to start nutrition, can provide adequate nutrition effectively, is safe in patients with low risk of aspiration, and as compared to the nasojejunal route of feeding carries a similar risk of exacerbation of pain, tolerance to EN, infectious complications, mortality, and length of hospital stay [112, 129, 153–161].

Nasojejunal feeding is preferred for EN in patients with a high risk of aspiration, who cannot tolerate gastric feeding, severe gastroparesis, partial gastric outlet obstruction due to pancreatic edema or pseudocysts, and in patients who have undergone minimally invasive necrosectomy [112, 117, 136, 162].

Mild acute pancreatitis: About 80% of acute pancreatitis patients experience a mild form of the disease that resolves on its own, allowing them to consume solid food without requiring nutritional support, such as EN or PN [6, 112]. In mild acute pancreatitis, starting with a soft low-fat solid diet is safe, effective (as it does not worsen abdominal pain, provides more calories than a clear liquid diet, and results in shorter hospital stays), and well-tolerated [146, 163–167]. Therefore, the traditional practice of initially providing a liquid diet and advancing to a solid oral diet is not recommended in mild acute pancreatitis.

Indications of PN

Routine use of PN is unnecessary, as PN is now known to be more expensive, riskier, and no more effective than EN in patients with acute pancreatitis. PN should not be initiated until all attempts are made with EN for at least 2–3 days. In acute pancreatitis, PN is indicated in selected patients [6, 112, 129, 133, 168, 169]:

- If EN is not possible or contraindications (e.g., prolonged paralytic ileus, duodenal obstruction from pancreatic edema or pseudocyst, complex pancreatic fistulae, hemodynamic instability, and the need for inotrope support).
- Unable to achieve targeted nutritional demand through EN.
- When enteral access cannot be maintained, or the patient cannot tolerate a nasal tube due to nasal irritation.
- If enteral feeding leads to exacerbation of abdominal pain and therefore, patients are unable to tolerate EN.
- In abdominal compartment syndrome with IAP >20 mmHg, patients cannot tolerate EN, and PN is indicated.

When tolerance to EN increases with recovery, the volume of PN should be decreased gradually, and PN should be transitioned to EN as soon as possible.

Nutritional requirements and management

Severe acute pancreatitis is characterized by substantial protein catabolism, so protein requirements are higher than in healthy individuals. Therefore, when PN is administered, a mixed source of energy from carbohydrates, fat, and protein should be preferred, and particular

attention should be given to avoiding overfeeding and hyperglycemia. Rough guidelines for nutritional requirements in severe acute pancreatitis are:

- Energy: 25–30 kcal/kg/day
- Protein: 1.2 to 1.5 gm/kg/day
- Carbohydrate: 4–6 gm/kg/day
- Lipid: up to 2 gm/kg/day

Carbohydrate supplementation: Hyperglycemia frequently occurs in patients with acute pancreatitis due to pancreatic endocrine dysfunction. Blood sugar should be monitored closely, and insulin treatment is recommended to treat hyperglycemia with a goal of keeping blood sugar less than 180 mg/dL (10 mmol/L).

Lipid infusion: As hypertriglyceridemia is an important cause of acute pancreatitis; lipids should be infused with proper monitoring of triglyceride levels. In the absence of severe hypertriglyceridemia (>350 mg/dL) or thrombocytopenia, IV lipids appear safe and effective, especially if glucose intolerance is present. The triglyceride level should be checked before initiating PN, monitored regularly, and kept below 400 mg/dL. When the triglyceride level exceeds 400 mg/dL (4.5 mmol/L), lipid infusion should be discontinued temporarily. To prevent hypertriglyceridemia, IV lipids should be administered gradually over a period of 10–12 hours.

Glutamine supplementation: The use of glutamine supplementation is beneficial and recommended in patients with severe acute pancreatitis receiving parenteral nutrition [112]. The advantages of glutamine are limited only to patients receiving parenteral nutrition, so do not supplement glutamine to patients of severe acute pancreatitis receiving enteral nutrition. The recommended dose of L-glutamine is 0.20 gm/kg per day, and glutamine supplementation in PN is found to reduce infectious complications and mortality [170, 171].

PERIOPERATIVE NUTRITION

Malnutrition in hospitalized patients is very common, with about 20% and 40% incidence [172]. Many major surgical diseases (e.g., malignancy, inflammation, gastrointestinal dysfunction, and burns) result in malnutrition, causing catabolic effects leading to inflammatory responses, protein catabolism, and nitrogen losses. Gastrointestinal surgery-related causes of malnutrition are pre-existing chronic disease, anorexia, prolonged ileus, pre and postoperative fasting, malabsorption syndrome, intestinal obstruction, and previous surgical bowel resection [173]. Compared with well-nourished patients, malnutrition in surgical patients is associated with detrimental effects like longer hospital stays, increased hospital costs, and increased postoperative morbidity and mortality (increased susceptibility to infection, poor wound healing, and risk for death after surgery) [174–176].

The decision to use PN in surgical patients depends on the state of health before surgery, the severity of malnutrition, whether the surgery is emergency or elective, the type of surgical procedure, the expected duration for return of normal gastrointestinal function, and how much energy and nutrient requirements patient can tolerate by oral or EN route postoperatively. PN is lifesaving in patients with prolonged gastrointestinal failure. Perioperative nutritional support aims to provide adequate macronutrients and micronutrients to minimize the catabolism and aggravation of malnutrition, promote muscle, immune, and cognitive functions, and decreases infectious and non-infectious postoperative complication

rates with resultant fast postoperative recovery [177, 178].

Preoperative parenteral nutrition

Preoperative PN is indicated in severely malnourished patients (weight loss >10–15%, serum albumin <3.0 gm/dL, body mass index (BMI) <18.5 or nutrition risk index (NRI) score <83.5) who cannot achieve adequate nutrition orally or enterally [179, 180]. Preoperative PN aims to provide adequate energy, protein, micronutrients and restore glycogen stores [181].

Preoperative PN for 7–10 days in severely malnourished patients reduces the rate of postoperative complications and improves outcome, provided the operation can be safely postponed [180, 181, 182]. Restoration of the nutritional and metabolic status usually takes about 7 to 14 days, and PN is continued in the postoperative period. In patients with mild to moderate malnutrition, surgery need not be delayed for preoperative PN or EN, and avoid preoperative PN in such patients.

Postoperative parenteral nutrition

Postoperative parenteral nutrition should not be used routinely because of the increased risk of postoperative complications [182, 183].

Indications of postoperative nutritional support

Postoperative PN is indicated in the following conditions [6, 179, 180, 184–186]:

- Previously well-nourished patients are unlikely to resume oral and enteral feeds within 10 days due to postoperative complications impairing gastrointestinal function and preventing normal oral feeding, such as intestinal obstruction. But in well-nourished patients with a delayed return of gut function likely to resume oral intake or EN within 7 days, PN is not indicated.
- Previously malnourished patients in whom oral intake or EN is not feasible or not tolerated within 5–7 days.
- In previously severely malnourished patients undergoing emergency surgery, initiate PN as soon as possible.
- Supplemental PN: Combining EN and PN should be considered for patients who require nutritional support but cannot meet at least 50% of their energy and nutrient needs via oral or enteral intake for more than seven days.

Timing of initiating PN in postoperative patients

The optimal timing of initiation of PN is determined based on the patient's clinical condition and preoperative nutritional status [6, 179, 180, 185].

- Immediate postoperative PN support (started on PO day 1) may be appropriate in patients as a continuation of preoperative nutritional support for severe malnutrition.
- Initiate PN as soon as possible in patients with severe malnutrition if oral intake or EN is unlikely.
- For patients who are nutritionally at risk and oral intake or EN is not possible, initiating PN within 3 to 5 days may be appropriate.
- In the absence of preoperative malnutrition, PN should be delayed for around 5 days after surgery as early PN does not provide any benefit in most non-critically ill patients [39, 187].
- Initiate supplemental PN after 7 days if oral and enteral intake alone cannot

achieve 50% or more of estimated energy and nutrient requirements in well-nourished, stable adult patients.

Common disorders for which postoperative PN is indicated include gastrointestinal anastomotic failure, gastrointestinal fistulas, postoperative mechanical bowel obstruction, diffuse peritonitis, paralytic ileus, severe acute pancreatitis, bowel ischemia, short bowel syndrome, etc.

In patients receiving PN postoperatively, supplement vitamins and trace elements with PN [177].

PULMONARY DISEASES

Nutritional considerations

There is a strong association between malnutrition and lung function. In chronic obstructive pulmonary disease (COPD), malnutrition is common (occurs in about 10% to 60% of patients) [188, 189] and is associated with higher morbidity, mortality rate, and healthcare costs [190–193].

The important causes of malnutrition in patients with COPD are decreased food intake, increased energy expenditure, depression, social isolation, aging, inflammation, and the use of medication such as corticosteroids [194].

- Effect of malnutrition on lung function: When calorie intake is inadequate in critically ill patients with pulmonary disorders, protein is catabolized to provide energy. When protein is used as a source of calories, it leads to catabolic muscle wasting. So, malnutrition can lead to reduced muscle strength and impairment of respiratory muscle function, which can decrease ventilatory drive and decreased response to hypoxia due to progressive diaphragmatic weakness with resultant precipitation or aggravation of respiratory failure [193, 195, 196]. Malnutrition-induced muscle weakness also adversely affects weaning from mechanical ventilators [197]. Moreover, malnutrition also alters pulmonary defense mechanisms and increases susceptibility to infection [198].
- Effect of pulmonary diseases on nutritional status: In advanced pulmonary diseases, a combination of, (a) Higher energy requirements due to increased work of breathing and systemic inflammation, and (b) Poor food intake lead to catabolism and resultant malnutrition and weight loss [199]. Underweight patients with the chronic pulmonary disease have a significantly increased risk of all-cause mortality [200].
- Effect of nutritional support on lung function: Nutritional support in COPD patients has shown modest improvement in various parameters such as respiratory (inspiratory and expiratory muscle strength) and non-respiratory (handgrip and quadriceps) muscle strength, respiratory muscle function, exercise tolerance, and quality of life and these benefits are greater in malnourished patients [201–205].

Nutritional requirements

Administration of nutrition by oral or enteral route is preferred. But if the gastrointestinal function is Administration of nutrition by oral or enteral route is preferred. But if the gastrointestinal function is impaired for a prolonged period, and adequate oral or EN is not feasible, PN is indicated. Patients with ARDS, COPD, respiratory failure and patients on mechanical ventilators need special consideration for their nutritional requirements. The nutritional needs of COPD patients vary and are

determined by their clinical state (stable or exacerbation) and disease severity (ranging from mild to very severe) [206]:

- In COPD, requirements of Energy and protein are higher in moderately or severely malnourished patients, acutely unwell patients with infection, and patients who exercise to increase muscle mass [193].
- The recommended energy intake for patients with COPD is about 30 kcal/kg/day for weight maintenance [207] and may be as high as 45 kcal/kg/day for patients aiming to achieve weight gain [208]. In malnourished patients, energy requirements may be as high as 1.7 of resting energy expenditure (REE) [209].
- The recommended daily protein requirement varies based on clinical status, as summarized in Table 56.6 [193].
- Avoid overfeeding: Excess supplementation of dextrose and lipids is harmful. Administration of total energy that exceeds energy requirements increases CO_2 production and the work of breathing, which may be detrimental in patients vulnerable to the retention of CO_2.
- Lipids in stable patients: In respiratory disorders, the use of lipids is suggested because it provides more energy with less production of CO_2 and therefore reduces the work of breathing. So in spontaneously ventilated patients with COPD, the use of a higher amount of lipids (up to about 50%) and lesser carbohydrates (about 30%) is preferred [210]. While administering lipid emulsion as a part of PN, selecting lipid preparation containing omega-3 fatty acids-rich fish-oil is beneficial due to its anti-inflammatory action in high-risk, critical patients with ARDS [64, 211].
- Lipids in patients on a ventilator: It is recommended to use a low carbohydrate formula, which contains more lipids and less carbohydrates, for patients on a ventilator as it may shorten the duration of mechanical ventilation [212–214]. However, several studies failed to demonstrate the reduction in the duration of ventilatory support [215, 216], and recent ASPEN-SCCM Clinical Guidelines (2016) recommend against the use of high-fat/low-carbohydrate formulations to manipulate the respiratory quotient and reduce CO_2 production in acute respiratory failure patients in ICU [6].
- As patients with acute respiratory failure are susceptible to fluid accumulation, a concentrated nutritional formula that restricts fluid volume is recommended [6].
- Avoid hypokalemia, hypophosphatemia, hypocalcemia, and hypomagnesemia because they can adversely affect the strength of respiratory muscles. To avoid these abnormalities caused by refeeding syndrome, it is important to gradually initiate PN in severely malnourished patients with respiratory disorders.
- Vitamin D deficiency is common in patients with COPD [217–219]. The low value of vitamin D carries the risk of recurrent pulmonary infections [220], worsening lung function [221], and faster decline in lung function [222].

Vitamin D supplementation substantially reduced the risk of respiratory tract infections [223] as well as the exacerbation rates of COPD [224, 225].

So, GOLD guidelines 2020 recommends screening all COPD patients hospitalized for exacerbations to detect vitamin D deficiency and supplement vitamin D if necessary [206].

Table 56.6 Protein requirement in COPD patients	
Requirements	**Clinical state**
0.8–1.5 gm/kg/d	Stable, non-malnourished COPD patients without nutritional risk
Up to 1.5 gm/kg/d	In acutely unwell (exacerbating) COPD patients, for daily requirements and avoid further protein losses For pulmonary rehabilitation, with exercise to gain or retain lean muscle mass Malnourished outpatients to achieve weight gain

SHORT BOWEL SYNDROME

Short bowel syndrome (SBS), also known as a small gut syndrome, is a relatively uncommon condition characterized by malabsorption which occurs most commonly due to extensive surgical resection of the small intestine.

Because of the short length of the remaining intestine, the area available for absorption reduces with the resultant malabsorption of macronutrients and/or water and electrolytes, causing diarrhea, dehydration, electrolyte imbalances, and malnutrition. These symptoms are severe if: (1) More than 75% of the small bowel is resected, (2) The terminal ileum and ileocaecal valve are removed, or (3) The remaining bowel is diseased with impaired absorption [226]. After massive intestinal resection, an intact colon, if in continuity, is vital in supporting the remaining small intestine in digestion and thereby reduces the dependency on PN [227–229].

The common causes of short bowel syndrome in adults are re-surgery performed for complications, mesenteric infarction, malignancy and radiation, surgical resection for crohn's disease, intestinal trauma, mesenteric vascular occlusion, and volvulus [230, 231].

Pathophysiology and presentations

- Severe diarrhea, electrolyte disturbances, and malnutrition: Loss of intestinal absorptive surface area, rapid transit time, and/or dysfunction of the remaining bowel reduces intestinal absorption leading to:
  - Large volume diarrhea, hypovolemia, metabolic acidosis, hypokalemia, hypomagnesemia, and hypocalcemia.
  - Malnutrition, weight loss, and deficit of water and fat-soluble vitamins.
- Gastric acid hypersecretion: Production of gastric acid secretion inhibitory hormones (normally secreted in the jejunum and distal ileum) reduces after the massive intestinal loss. Due to the loss of inhibitory hormones, gastrin levels increase, stimulating gastric acid secretion [232, 233].
- D-lactic acidosis: Bacterial fermentation of malabsorbed carbohydrates in the colon produces a substantial amount of D-lactic acid, which can lead to high anion gap metabolic acidosis [234].
- Nephrolithiasis: Due to multiple factors, the risk of calcium oxalate nephrolithiasis is high in patients with SBS [235, 236]. Normally oxalate in the diet combines with intraluminal calcium and is excreted in stool as insoluble calcium oxalate. In patients with SBS, large amounts of unabsorbed fat are available, and calcium preferentially binds with the same in the intact colon due to malabsorption. The resultant increased

unbound oxalate is absorbed freely and rapidly by the intact colon leading to hyperoxaluria, which predisposes patients to a higher risk of oxalate stone formation [237]. In patients with SBS, chronic dehydration, hypocitraturia, hypomagnesuria, low urine volume, and low pH increases the risk of developing kidney stones [235, 236]. In addition, in patients with SBS, multiple factors like chronic dehydration, hypocitraturia, hypomagnesuria, low urine volume, and low pH increases the risk of developing kidney stones [235, 238].

Nutritional management

Before the advent of PN, survival in acute SBS was very poor. The selection of nutritional treatment is based upon the severity of SBS and frequently needs home parenteral nutrition in severe cases. The need for nutrition requirement is variable in SBS, and it ranges from temporary support in the postoperative period to long-term supplementation depending on how much of the gastrointestinal tract is left, the site of resection, and the presence of the colon in continuity with the small bowel. Patients with SBS generally need PN when the length of the remaining functional small bowel is <50–70 cm with the presence of a colon in continuity or the length of the small bowel is <100–150 cm when the colon is absent [228, 239]. The metabolic and nutrient therapy of SBS is divided into 3 clinical stages:

1. First acute stage: The initial acute phase following resection usually lasts for three to four weeks and is characterized by large-volume diarrhea causing significant losses of fluid and electrolytes:

- In the initial acute phase of illness, patients need prompt administration of electrolytes containing intravenous fluids in large volumes to replace huge losses and correct fluid and electrolyte disturbances. The selection of IV fluid is based on existing electrolyte and acid-base disturbance, but supplementing balanced crystalloids or half normal saline with potassium is usually adequate.
- In critically ill unstable patients, patients should be kept NPO (nothing by mouth). Oral intake is not adequate in the majority of such patients at this stage and may carry the risk of aspiration and, therefore, can be harmful.
- PN is indicated if EN is not possible within one week in patients with severe SBS. PN is initiated only after correcting fluid and electrolyte disturbances and achieving hemodynamic stability. PN is the primary source of nutrition in the initial phase, but progression to EN is attempted when the bowel begins to adapt.
- Supplemental oral or EN helps to prevent mucosal atrophy and is essential to promote gut adaptation but administer combined feeding cautiously to avoid overfeeding [231]. EN in bolus form may cause diarrhea, so slow continuous overnight tube feeding is recommended in the initial acute phase, and it significantly increases the net absorption of lipids, proteins, and energy [240].

2. Second adaptive stage: Structural adaptation (hyperplasia with the resultant increase in absorptive surface area) and functional adaptation (slowed transit time to allow increased nutrient absorption) of the bowel may last for up to 2 years [231]:

- As enteral feeding is necessary for bowel adaptation in SBS, it should be started as soon as the volume of fecal loss decreases. The PN is reduced gradually, and oral or enteral intake is increased with caution to avoid

excessive diarrhea and aim to provide adequate nutrition.

- In patients requiring PN, administration of a minimal 1 gm/kg/week of intravenous lipid emulsion is recommended to prevent essential fatty acid (EFA) deficiency [230].
- Overfeeding and the use of soybean-based lipid emulsions in patients receiving long-term PN increases the risk of intestinal failure-associated liver disease (IFALD) [241]. On the other hand, IV fish oil-containing lipid emulsions reduce the risk of IFALD in these patients [242–244].
- Administration of glutamine in either PN or EN is not recommended in SBS patients [230].
- As patients with SBS are at risk for fat-soluble vitamin deficiency, supplementation of vitamins A, D, E, and K is necessary [226].
- If the terminal ileum is resected or resection is greater than 100 cm of ileum, an injection of vitamin B12 should be given monthly [245].
- Hypomagnesemia is common because of the malabsorption of magnesium due to loss of the distal ileum, and its management consists of supplementation of magnesium and correction of sodium depletion [226, 246].

3. Third maintenance stage: In about 50% of adult patients, intestinal adaptation occurs significantly, and intestinal failure reverses completely within the first two years. No further improvement or adaptive changes occur in this stable phase, so long-term treatment is planned:

- The selection of treatment is based on the severity of SBS. Most patients with a severe type of SBS need home-based parenteral nutrition (HPN) for months to years or lifelong. Patients with adequate adaptation and absorption may not need PN.
- In patients with home-based PN, continuous PN infusion is avoided, and overnight cycle PN is recommended because it reduces the risk of intestinal failure associated liver disease (IFALD) [230], provides freedom from the infusion pump during the day, and maximizes the convenience of patients [247].
- Oral diet or EN is started using small volume and should be advanced slowly to small frequent meals [248].
- Patients with D-lactic acidosis need appropriate hydration, restriction of carbohydrate containing diet and administration of non-absorbable antibiotics against D-lactate forming bacteria, and thiamine supplementation.

REFERENCES

1. Fiaccadori E, Lombardi M, Leonardi S, et al. Prevalence and clinical outcome associated with preexisting malnutrition in acute renal failure: a prospective cohort study. J Am Soc Nephrol. 1999;10(3):581–93.
2. Cano NJ, Aparicio M, Brunori G, et al. ESPEN guidelines on parenteral nutrition: adult renal failure. Clin Nutr. 2009;28(4):401–14.
3. Li C, Xu L, Guan C, et al. Malnutrition screening and acute kidney injury in hospitalised patients: a retrospective study over a 5-year period from China. Br J Nutr. 2020;123(3):337–346.
4. Meyer D, Mohan A, Subev E, et al. Acute kidney injury incidence in hospitalized patients and implications for nutrition support. Nutr Clin Pract. 2020;35(6):987–1000.
5. Bufarah MNB, Costa NA, Losilla MPRP, et al. Low caloric and protein intake is associated with mortality in patients with acute kidney injury. Clin Nutr ESPEN. 2018;24:66–70.
6. McClave SA, Taylor BE, Martindale RG, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). JPEN J Parenter Enteral Nutr 2016;40(2):159–211.
7. Kellum JA, Lameire N, Aspelin P, et al. KDIGO clinical practice guideline for acute kidney injury. Kidney Int Suppl. 2012;2(1):1–138.
8. Blumenkrantz MJ, Kopple JD, Koffler A, et al. Total parenteral nutrition in the management of acute renal failure. Am J Clin Nutr. 1978;31(10):1831–40.

9. Gunst J, Vanhorebeek I, Casaer MP, et al. Impact of early parenteral nutrition on metabolism and kidney injury. J Am Soc Nephrol. 2013;24(6):995–1005.
10. Casaer MP, Mesotten D, Hermans G, et al. Early versus late parenteral nutrition in critically ill adults. N Engl J Med. 2011;365(6):506–17.
11. Singer P, Blaser AR, Berger MM, et al. ESPEN guideline on clinical nutrition in the intensive care unit. Clin Nutr. 2019;38(1):48–79.
12. Appropriate Dosing for Parenteral Nutrition: ASPEN Recommendations. American Society Parenteral and Enteral Nutrition 2019. http://www.nutritioncare.org/uploadedFiles/Documents/Guidelines_and_Clinical_Resources/PN%20Dosing%201-Sheet-FINAL.pdf.
13. Druml W, Kierdorf HP, Working group for developing the guidelines for parenteral nutrition of The German Association for Nutritional M. Parenteral nutrition in patients with renal failure – Guidelines on Parenteral Nutrition, Chapter 17. Ger Med Sci 2009;7:Doc11.
14. Gervasio JM, Garmon WP, Holowatyj M. Nutrition support in acute kidney injury. Nutr Clin Pract. 2011;26(4):374–81.
15. Honoré PM, De Waele E, Jacobs R, et al. Nutritional and metabolic alterations during continuous renal replacement therapy. Blood Purif. 2013;35(4):279–84.
16. Bellomo R, Cass A, Cole L, et al. Calorie intake and patient outcomes in severe acute kidney injury: findings from The Randomized Evaluation of Normal vs. Augmented Level of Replacement Therapy (RENAL) study trial. Crit Care. 2014;18(2):R45.
17. Sabatino A, Fiaccadori E. Critically ill patient on renal replacement therapy: nutritional support by enteral and parenteral routes. In: Rajendram R, Preedy VR, Patel VB, eds. Diet and Nutrition in Critical Care. Springer-Verlag New York; 2015:671–683.
18. Oh WC, Mafrici B, Rigby M, et al. Micronutrient and amino acid losses during renal replacement therapy for acute kidney injury. Kidney Int Rep 2019;4(8):1094–1108.
19. Patel JJ, McClain CJ, Sarav M, et al. Protein Requirements for critically ill patients with renal and liver failure. Nutr Clin Pract. 2017;32(1_suppl):101S–111S.
20. Rousseau AF, Losser MR, Ichai C, et al. ESPEN endorsed recommendations: Nutritional therapy in major burns. Clin Nutr. 2013;32(4):497–502.
21. Chourdakis M, Bouras E, Shields BA, et al. Nutritional therapy among burn injured patients in the critical care setting: An international multicenter observational study on “best achievable” practices. Clin Nutr. 2020;39(12):3813–3820.
22. Williams FN, Branski LK, Jeschke MG, et al. What, how, and how much should patients with burns be fed? Surg Clin North Am. 2011;91(3):609–29.
23. Clark A, Imran J, Madni T, et al. Nutrition and metabolism in burn patients. Burns Trauma. 2017;5:11.
24. Wise AK, Hromatka KA, Miller KR. Energy Expenditure and protein requirements following burn injury. Nutr Clin Pract. 2019;34(5):673–680.
25. Jeschke, MG. Clinical review: Glucose control in severely burned patients - current best practice. Crit Care 2013;17(4):232.
26. Hébuterne X, Lemarié E, Michallet M, et al. Prevalence of malnutrition and current use of nutrition support in patients with cancer. JPEN J Parenter Enteral Nutr. 2014;38(2):196–204.
27. Arends J, Baracos V, Bertz H, et al. ESPEN expert group recommendations for action against cancer-related malnutrition. Clin Nutr. 2017;36(5):1187–1196.
28. Mattox TW. Cancer cachexia: cause, diagnosis, and treatment. Nutr Clin Pract. 2017;32(5):599–606.
29. Bozzetti F, Arends J, Lundholm K, et al. ESPEN guidelines on parenteral nutrition: non-surgical oncology. Clin Nutr. 2009;28(4):445–54.
30. Virizuela JA, Camblor-Álvarez M, Luengo-Pérez LM, et al. Nutritional support and parenteral nutrition in cancer patients: an expert consensus report. Clin Transl Oncol. 2018;20(5):619–629.
31. Yalcin S, Gumus M, Oksuzoglu B, et al. Turkey Medical Oncology Active Nutrition Platform. Nutritional aspect of cancer care in medical oncology patients. Clin Ther. 2019;41(11):2382–2396.
32. Anker SD, Laviano A, Filippatos G, et al. ESPEN Guidelines on parenteral nutrition: on cardiology and pneumology. Clin Nutr. 2009;28(4):455–60.
33. Lew CCH, Yandell R, Fraser RJL, et al. Association between malnutrition and clinical outcomes in the intensive care unit: a systematic review. JPEN J Parenter Enteral Nutr 2017;41(5):744–58.
34. Singer P, Berger MM, Van den Berghe G, et al. ESPEN guidelines on parenteral nutrition: intensive care clinical nutrition 2009;28(4):387–400.
35. Tappenden KA, Quatrara B, Parkhurst ML, et al. Critical role of nutrition in improving quality of care: an interdisciplinary call to action to address adult hospital malnutrition. JPEN J Parenter Enteral Nutr. 2013;37(4):482–97.
36. Singer P. Preserving the quality of life: nutrition in the ICU. Crit Care 2019;23:139.
37. van Zanten ARH, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Crit Care 2019;23:368.
38. Canadian Critical Care Society (CCCS) and Canadian Critical Care Trials Group (CCTG). (2015) Canadian Clinical Practice Guidelines: Summary of Revisions to the Recommendations, [Online], Available at: https://www.criticalcarenutrition.com/docs/CPGs%202015/Summary%20CPGs%202015%20vs%202013.pdf.
39. Harvey SE, Parrott F, Harrison DA, et al; CALORIES Trial Investigators. Trial of the route of early nutritional support in critically ill adults. N Engl J Med. 2014;371(18):1673–1684.
40. Elke G, van Zanten AR, Lemieux M, et al. Enteral versus parenteral nutrition in critically ill patients: an updated systematic review and meta-analysis of randomized controlled trials. Crit Care. 2016;20(1):117.

41. TARGET Investigators, for the ANZICS Clinical Trials Group, Chapman M, Peake SL, et al. Energy-dense versus routine enteral nutrition in the critically ill. N Engl J Med. 2018;379(19):1823–34.
42. Rice TW, Wheeler AP, Thompson BT, et al. Initial trophic vs full enteral feeding in patients with acute lung injury: the EDEN randomized trial. JAMA. 2012;307(8):795–803.
43. The magnificent seven. Evidence based quality principles agreed by all critical care units in the east of England. https://drive.google.com/file/d/0BwwIbI4F418eGpuaFg4Z1RGZlE/view.
44. Lambell KJ, Tatucu-Babet OA, Chapple LA, et al. Nutrition therapy in critical illness: a review of the literature for clinicians. Crit Care. 2020;24(1):35.
45. Weijs PJ, Looijaard WG, Beishuizen A, et al. Early high protein intake is associated with low mortality and energy overfeeding with high mortality in non-septic mechanically ventilated critically ill patients. Crit Care. 2014;18(6):701.
46. Tian F, Wang X, Gao X, et al. Effect of initial calorie intake via enteral nutrition in critical illness: a meta-analysis of randomised controlled trials. Crit Care. 2015;19(1):180.
47. Zusman O, Theilla M, Cohen J, et al. Resting energy expenditure, calorie and protein consumption in critically ill patients: a retrospective cohort study. Crit Care. 2016;20(1):367.
48. Doig GS, Simpson F, Heighes PT, et al. Restricted versus continued standard caloric intake during the management of refeeding syndrome in critically ill adults: a randomised, parallel-group, multicentre, single-blind controlled trial. Lancet Respir Med. 2015;3(12):943–52.
49. Puthucheary ZA, Rawal J, McPhail M, et al. Acute skeletal muscle wasting in critical illness. JAMA. 2013;310(15):1591–600.
50. van Gassel RJJ, Baggerman MR, van de Poll MCG. Metabolic aspects of muscle wasting during critical illness. Curr Opin Clin Nutr Metab Care. 2020;23(2):96–101.
51. Nicolo M, Heyland DK, Chittams J, et al. Clinical outcomes related to protein delivery in a critically ill population: a multicenter, multinational observation study. JPEN J. Parenter. Enter. Nutr. 2016;40(1):45–51.
52. Weijs PJM, Mogensen KM, Rawn JD, et al. Protein intake, nutritional status and outcomes in ICU survivors: a single center cohort study. J Clin Med. 2019;8(1):43.
53. Suzuki G, Ichibayashi R, Yamamoto S, et al. Effect of high-protein nutrition in critically ill patients: A retrospective cohort study. Clin Nutr ESPEN. 2020;38:111–117.
54. Koekkoek WACK, van Setten CHC, Olthof LE, et al. Timing of PROTein INtake and clinical outcomes of adult critically ill patients on prolonged mechanical VENTilation: The PROTINVENT retrospective study. Clin Nutr. 2019;38(2):883–890.
55. Burtin C, Clerckx B, Robbeets C, et al. Early exercise in critically ill patients enhances short-term functional recovery. Crit Care Med. 2009;37(9):2499–505.
56. Schaller SJ, Anstey M, Blobner M, et al. International Early SOMS-guided Mobilization Research Initiative. Early, goal-directed mobilisation in the surgical intensive care unit: a randomised controlled trial. Lancet. 2016;388(10052):1377–1388.
57. Bolder U, Ebener C, Hauner H, et al. Working group for developing the guidelines for parenteral nutrition of The German Association for Nutritional Medicine. Carbohydrates - guidelines on parenteral nutrition, chapter 5. Ger Med Sci 2009;7:Doc23.
58. Silva-Perez LJ, Benitez-Lopez MA, Varon J, et al. Management of critically ill patients with diabetes. World J Diabetes. 2017;8(3):89–96.
59. Jacobi J, Bircher N, Krinsley J, et al. Review guidelines for the use of an insulin infusion for the management of hyperglycemia in critically ill patients. Crit Care Med. 2012;40(12):3251–76.
60. Singer P, Berger MM, Van den Berghe G, et al. ESPEN guidelines on parenteral nutrition: intensive care. Clin Nutr 2009;33:246–251.
61. Calder PC, Jensen GL, Koletzko BV, et al. Lipid emulsions in parenteral nutrition of intensive care patients: current thinking and future directions. Intensive Care Med. 2010;36(5):735–49.
62. Mundi MS, Salonen BR, Bonnes SL, et al. Parenteral nutrition lipid emulsions and potential complications. Practical Gastroenterology 2017;41(8):32–37.
63. Pradelli L, Mayer K, Klek S, et al. ω-3 Fatty-acid enriched parenteral nutrition in hospitalized patients: systematic review with meta-analysis and trial sequential analysis. JPEN J Parenter Enteral Nutr 2020;44(1):44–57.
64. Martindale RG, Berlana D, Boullata JI, et al. Summary of proceedings and expert consensus statements from the international summit "Lipids in Parenteral Nutrition". JPEN J Parenter Enteral Nutr. 2020;44(Suppl 1):S7–S20.
65. Calder PC, Adolph M, Deutz NEP, et al. Lipids in the intensive care unit: report from the ESPEN Expert group. ClinNutr 2018;37:1–18.
66. Manzanares W, Dhaliwal R, Jiang X, et al. Antioxidant micronutrients in the critically ill: a systematic review and meta-analysis. Crit Care. 2012;16(2):R66.
67. Canadian Clinical Practice Guidelines for Nutrition Support in the Mechanically Ventilated, Critically Ill Adult, 9.4a Composition of PN: Glutamine (CCCN) 2015 https://www.criticalcarenutrition.com/docs/CPGs%202015/4.1c%202015.pdf.
68. Szczygie B, Pertkiewicz M, Naber T, et al. Basics in clinical nutrition: Nutrition support in GI fistulas. the European e-Journal of Clinical Nutrition and Metabolism 2009;4:e313–e314.
69. Williams LJ, Zolfaghari S, Boushey RP. Complications of enterocutaneous fistulas and their management. Clin Colon Rectal Surg. 2010;23(3):209–220.
70. Kumar P, Maroju NK, Kate V. Enterocutaneous fistulae: etiology, treatment, and outcome-a study from South India. Saudi J Gastroenterol. 2011;17:391–5.

71. Polk TM, Schwab CW. Metabolic and nutritional support of the enterocutaneous fistula patient: a three-phase approach. World J Surg 2012;36:524–533.
72. Tang QQ, Hong ZW, Ren HJ, et al. Nutritional management of patients with enterocutaneous fistulas: practice and progression. Front Nutr. 2020;7:564379.
73. Kumpf VJ, de Aguilar-Nascimento JE, Diaz-Pizarro Graf JI, et al. FELANPE; American Society for Parenteral and Enteral Nutrition. ASPEN-FELANPE Clinical Guidelines: Nutrition Support of Adult Patients with Enterocutaneous Fistula. JPEN J Parenter Enteral Nutr. 2017;41(1):104–112.
74. Grainger JT, Maeda Y, Donnelly SC, et al. Assessment and management of patients with intestinal failure: a multidisciplinary approach. Clin Exp Gastroenterol. 2018;11:233–241.
75. Gribovskaja-Rupp I, Melton GB. Enterocutaneous fistula: proven strategies and updates. Clin Colon Rectal Surg 2016; 29:130.
76. Evenson AR, Fischer JE. Current management of enterocutaneous fistula. Journal of gastrointestinal surgery: official journal of the Society for Surgery of the Alimentary Tract. 2006;10:455–64.
77. Casanova MJ, Chaparro M, Molina B, et al. Prevalence of malnutrition and nutritional characteristics of patients with inflammatory bowel disease. J Crohn's Colitis. 2017;11(12):1430–9.
78. Nguyen GC, Munsell M, Harris ML. Nationwide prevalence and prognostic significance of clinically diagnosable protein-calorie malnutrition in hospitalized inflammatory bowel disease patients. Inflamm Bowel Dis. 2008;14(8):1105–11.
79. Pulley J, Todd A, Flatley C, et al. Malnutrition and quality of life among adult inflammatory bowel disease patients. JGH Open. 2019;4(3):454–460.
80. Balestrieri P, Ribolsi M, Guarino MPL, et al. Nutritional aspects in inflammatory bowel diseases. Nutrients. 2020;12(2):372.
81. Forbes A, Escher J, Hebuterne X, et al. ESPEN guideline: Clinical nutrition in inflammatory bowel disease. Clin Nutr. 2017;36:321–47.
82. Bischoff SC, Escher J, Hebuterne X, et al. ESPEN practical guideline: clinical nutrition in inflammatory bowel disease. Clin Nutr. 2020;39:632–53.
83. Lamb CA, Kennedy NA, Raine T, et al. British Society of Gastroenterology consensus guidelines on the management of inflammatory bowel disease in adults. Gut. 2019:68(Suppl 3):s1–s106.
84. Sood A, Ahuja V, Kedia S, et al. Diet and inflammatory bowel disease: The Asian Working Group guidelines. Indian J Gastroenterol. 2019;38(3):220–246.
85. Nutritional status in cirrhosis. Italian multicentre cooperative project on nutrition in liver cirrhosis. J Hepatol 1994;21:317–25.
86. Cheung K, Lee SS, Raman M. Prevalence and mechanisms of malnutrition in patients with advanced liver disease, and nutrition management strategies. Clin Gastroenterol Hepatol 2012;10(2):117–25.
87. Saunders J, Brian A, Wright M, et al. Malnutrition and nutrition support in patients with liver disease. Frontline Gastroenterol. 2010;1(2):105–111.
88. Dasarathy S. Consilience in sarcopenia of cirrhosis. J Cachexia Sarcopenia Muscle 2012;3:225–237.
89. Huisman EJ, Trip EJ, Siersema PD, et al. Protein energy malnutrition predicts complications in liver cirrhosis. Eur J Gastroenterol Hepatol 2011;23:982–989.
90. Alberino F, Gatta A, Amodio P, et al. Nutrition and survival in patients with liver cirrhosis. Nutrition 2001;17(6):445–450.
91. Sam J, Nguyen GC. Protein-calorie malnutrition as a prognostic indicator of mortality among patients hospitalized with cirrhosis and portal hypertension. Liver Int 2009;29(9):1396–402.
92. European Association for the Study of the Liver. Electronic address: easloffice@easloffice.eu, European Association for the Study of the Liver. EASL Clinical Practice Guidelines on nutrition in chronic liver disease. J Hepatol 2019;70(1):172–193.
93. Plauth M, Schuetz T, Working group for developing the guidelines for parenteral nutrition of The German Association for Nutritional Medicine. Hepatology - Guidelines on Parenteral Nutrition, Chapter 16. Ger Med Sci. 2009;7:Doc12.
94. Plauth M, Bernal W, Dasarathy S, et al. ESPEN guideline on clinical nutrition in liver disease. Clin Nutr 2019;38(2):485–521.
95. Bischoff SC, Bernal W, Dasarathy S, et al. ESPEN practical guideline: Clinical nutrition in liver disease. Clin Nutr. 2020;39(12):3533–3562.
96. Maharshi S, Sharma BC, Sachdeva S, et al. Efficacy of nutritional therapy for patients with cirrhosis and minimal hepatic encephalopathy in a randomized trial. Clin Gastroenterol Hepatol. 2016;14(3):454–460.e453.
97. Kato A, Tanaka H, Kawaguchi T, et al. Nutritional management contributes to improvement in minimal hepatic encephalopathy and quality of life in patients with liver cirrhosis: a preliminary, prospective, open-label study. Hepatol Res. 2013;43(5):452–458.
98. Amodio P, Bemeur C, Butterworth R, et al. The nutritional management of hepatic encephalopathy in patients with cirrhosis: International Society for Hepatic Encephalopathy and Nitrogen Metabolism Consensus. Hepatology. 2013;58(1):325–336.
99. Gheorghe L, Iacob R, Vădan R, et al. Improvement of hepatic encephalopathy using a modified high-calorie high-protein diet. Rom J Gastroenterol.2005;14(3):231–8.
100. Cordoba J, Lopez-Hellin J, Planas M, et al. Normal protein diet for episodic hepatic encephalopathy: results of a randomized study. Journal of hepatology. 2004;41(1):38–43.
101. Saja MF, Abdo AA, Sanai FM, et al. The coagulopathy of liver disease: does vitamin K help? Blood Coagul Fibrinolysis. 2013;24(1):10–7.
102. Aldrich SM, Regal RE. Routine Use of Vitamin K in the treatment of cirrhosis-related coagulopathy: Is it A-O-K? Maybe not, we say. P T. 2019;44(3):131–136.

103. Takuma Y, Nouso K, Makino Y, et al. Clinical trial: oral zinc in hepatic encephalopathy. Aliment Pharmacol Ther. 2010;32(9):1080–90.
104. Katayama K, Saito M, Kawaguchi T, et al. Effect of zinc on liver cirrhosis with hyperammonemia: a preliminary randomized, placebo-controlled double-blind trial. Nutrition 2014;30(11–12):1409–1414.
105. Mousa N, Abdel-Razik A, Zaher A, et al. The role of antioxidants and zinc in minimal hepatic encephalopathy: a randomized trial. Therap Adv Gastroenterol. 2016;9(5):684–91.
106. Shen YC, Chang YH, Fang CJ, et al. Zinc supplementation in patients with cirrhosis and hepatic encephalopathy: a systematic review and meta-analysis. Nutr J. 2019;18(1):34.
107. Al-Alfy M, Amin Hegazy A, Soliman Hammad K, et al. Zinc replacement in hepatic encephalopathy among the Egyptian patients. Al-Azhar Medical Journal 2020;49(2):839–848.
108. John S, Thuluvath PJ. Hyponatremia in cirrhosis: pathophysiology and management. World J Gastroenterol. 2015;21(11):3197–3205.
109. Aithal GP, Palaniyappan N, China L, et al. Guidelines on the management of ascites in cirrhosis Gut 2021;70(1):9–29.
110. Haberl J, Zollner G, Fickert P, et al. To salt or not to salt?-That is the question in cirrhosis. Liver Int. 2018;38(7):1148–1159.
111. Baron TH, Morgan DE. Acute necrotizing pancreatitis. N Engl J Med. 1999;340(18):1412–7.
112. Arvanitakis M, Ockenga J, Bezmarevic M, et al. ESPEN guideline on clinical nutrition in acute and chronic pancreatitis. Clin Nutr. 2020;39(3):612–631.
113. Zheng Z, Ding Y, Qu Y, et al. A narrative review of acute pancreatitis and its diagnosis, pathogenetic mechanism, and management. Ann Transl Med 2021;9(1):69.
114. Niederau C, Niederau M, Lüthen R, et al. Pancreatic exocrine secretion in acute experimental pancreatitis. Gastroenterology 1990;99(4):1120–1127.
115. Boreham B, Ammori BJ. A prospective evaluation of pancreatic exocrine function in patients with acute pancreatitis: correlation with extent of necrosis and pancreatic endocrine insufficiency. Pancreatology 2003;3(4):303–308.
116. Boxhoorn L, Voermans RP, Bouwense SA, et al. Acute pancreatitis. Lancet 2020;396(10252):726–34.
117. Lakananurak N, Gramlich L. Nutrition management in acute pancreatitis: Clinical practice consideration. World J Clin Cases. 2020;8(9):1561–1573.
118. Mederos MA, Reber HA, Girgis MD. Acute pancreatitis: a review. JAMA. 2021;325(4):382–390.
119. Ioannidis O, Lavrentieva A, Botsios D. Nutrition support in acute pancreatitis. JOP. 2008;9(4):375–90.
120. Mutch KL, Heidal KB, Gross KH, et al. Cost-analysis of nutrition support in patients with severe acute pancreatitis. Int J Health Care Qual Assur. 2011;24(7):540–547.
121. Uomo G. Pancreatic rest or not? The debate on the nutrition in acute pancreatitis continues JOP. 2013;14(2):216–7.
122. Rinninella E, Annetta MG, Serricchio M, et al. Nutritional support in acute pancreatitis: from physiopathology to practice: an evidence-based approach. Eur Rev Med Pharmacol Sci 2017;21(2):421–432.
123. Crockett SD, Wani S, Gardner TB, et al. American Gastroenterological Association Institute Clinical Guidelines Committee. American Gastroenterological Association Institute Guideline on Initial Management of Acute Pancreatitis. Gastroenterology. 2018;154(4):1096–1101.
124. Al-Omran M, Albalawi ZH, Tashkandi MF, et al. Enteral versus parenteral nutrition for acute pancreatitis. Cochrane Database Syst Rev. 2010;(1):CD002837.
125. Vaughn VM, Shuster D, Rogers MAM, et al. Early versus delayed feeding in patients with acute pancreatitis: a systematic review. Ann Intern Med. 2017;166(12):883–892.
126. Li W, Liu J, Zhao S, et al. Safety and efficacy of total parenteral nutrition versus total enteral nutrition for patients with severe acute pancreatitis: a meta-analysis. J Int Med Res 2018;46(9):3948–58.
127. Wu P, Li L, Sun W. Efficacy comparisons of enteral nutrition and parenteral nutrition in patients with severe acute pancreatitis: a meta-analysis from randomized controlled trials. Biosci Rep 2018;38(6):BSR20181515.
128. Yao H, He C, Deng L, et al. Enteral versus parenteral nutrition in critically ill patients with severe pancreatitis: a meta-analysis. Eur J Clin Nutr 2018;72(1):66–68.
129. Tenner S, Baillie J, DeWitt J, et al. American College of Gastroenterology guideline: management of acute pancreatitis. Am J Gastroenterol 2013;108(9):1400–1415.
130. Greenberg JA, Hsu J, Bawazeer M, et al. Clinical practice guideline: management of acute pancreatitis. Can J Surg. 2016;59(2):128–140.
131. Reintam Blaser A, Starkopf J, Alhazzani W, et al. Early enteral nutrition in critically ill patients: ESICM clinical practice guidelines. Intensive Care Med 2017;43(3):380–98.
132. National Institute for Health and Care Excellence. Pancreatitis (NICE guideline NG104). 2018. www.nice.org.uk/guidance/ng104.
133. Leppäniemi A, Tolonen M, Tarasconi A, et al. 2019 WSES guidelines for the management of severe acute pancreatitis. World J Emerg Surg 2019;14:27.
134. Petrov MS, Kukosh MV, Emelyanov NV. A randomized controlled trial of enteral versus parenteral feeding in patients with predicted severe acute pancreatitis shows a significant reduction in mortality and in infected pancreatic complications with total enteral nutrition. Dig Surg 2006;23(5–6):336–344.
135. Petrov MS, Pylypchuk RD, Uchugina AF. A systematic review on the timing of artificial nutrition in acute pancreatitis. Br J Nutr 2009;101(6):787–93.
136. Ramanathan M, Aadam AA. Nutrition management in acute pancreatitis. Nutr Clin Pract 2019;34(S1):S7–S12.

137. Li JY, Yu T, Chen GC, et al. Enteral nutrition within 48 hours of admission improves clinical outcomes of acute pancreatitis by reducing complications: a meta-analysis. PLoS One 2013;8(6):e64926.
138. Wereszczynska-Siemiatkowska U, Swidnicka-Siergiejko A, Siemiatkowski A, et al. Early enteral nutrition is superior to delayed enteral nutrition for the prevention of infected necrosis and mortality in acute pancreatitis. Pancreas. 2013;42(4):640–646.
139. Wu XM, Liao YW, Wang HY, et al. When to initialize enteral nutrition in patients with severe acute pancreatitis? A retrospective review in a single institution experience (2003–2013). Pancreas 2015;44(3):507–11.
140. Feng P, He C, Liao G, et al. Early enteral nutrition versus delayed enteral nutrition in acute pancreatitis A PRISMA-compliant systematic review and meta-analysis. Medicine. 2017;96(96):e8648.
141. Song J, Zhong Y, Lu X, et al. Enteral nutrition provided within 48 hours after admission in severe acute pancreatitis: a systematic review and meta-analysis. Medicine (Baltimore) 2018;97(34):e11871.
142. Bakker OJ, van Brunschot S, Farre A, et al. Timing of enteral nutrition in acute pancreatitis: meta-analysis of individuals using a single-arm of randomised trials. Pancreatology 2014;14(5):340–6.
143. Qi D, Yu B, Huang J, et al. Meta-analysis of early enteral nutrition provided within 24 hours of admission on clinical outcomes in acute pancreatitis. JPEN J Parenter Enteral 2018;42(7):1139–47.
144. Eckerwall GE, Tingstedt BB, Bergenzaun PE, et al. Immediate oral feeding in patients with mild acute pancreatitis is safe and may accelerate recovery–a randomized clinical study. Clin Nutr 2007;26(6):758–63.
145. Bakker OJ, van Brunschot S, van Santvoort HC, et al. Early versus on-demand nasoenteric tube feeding in acute pancreatitis. N Engl J Med. 2014;371(21):1983–1993.
146. Horibe M, Nishizawa T, Suzuki H, et al. Timing of oral refeeding in acute pancreatitis: A systematic review and meta-analysis. United European Gastroenterol J. 2016;4(6):725–732.
147. Lozada-Hernández EE, Barrón-González O, Vázquez-Romero S, et al. Non-inferiority comparative clinical trial between early oral REFEEDING and usual oral REFEEDING in predicted mild acute biliary pancreatitis. BMC Gastroenterol. 2020;20(1):228.
148. Spanier BWM, Bruno MJ, Mathus-Vliegen EM. Enteral nutrition and acute pancreatitis: a review. Gastroenterol Res Pract. 2011;2011:857949.
149. Working Group IAP/APA Acute Pancreatitis Guidelines. IAP/APA evidence-based guidelines for the management of acute pancreatitis. Pancreatology. 2013;13(4 suppl 2):e1–15.
150. Meier R, Ockenga J, Pertkiewicz J, et al. ESPEN guidelines on enteral nutrition: Pancreas. Clin Nutr. 2006;25(2):275–284.
151. Olah A, Romics Jr. L. Enteral nutrition in acute pancreatitis: A review of the current evidence. World J Gastroenterol. 2014;20(43):16123–16131.
152. Sun JK, Li WQ, Ke L, et al. Early enteral nutrition prevents intra-abdominal hypertension and reduces the severity of severe acute pancreatitis compared with delayed enteral nutrition: a prospective pilot study. World J Surg. 2013;37(9):2053–2060.
153. Eatock FC, Chong P, Menezes N, et al. A randomized study of early nasogastric versus nasojejunal feeding in severe acute pancreatitis. Am J Gastroenterol 2005;100:432–9.
154. Kumar A, Singh N, Prakash S, et al. Early enteral nutrition in severe acute pancreatitis: A prospective randomized controlled trial comparing nasojejunal and nasogastric routes. J Clin Gastroenterol. 2006;40(5):431–434.
155. Petrov MS, Correia MI, Windsor JA. Nasogastric tube feeding in predicted severe acute pancreatitis. A systematic review of the literature to determine safety and tolerance. JOP 2008;9(4):440–8.
156. Singh N, Sharma B, Sharma M, et al. Evaluation of early enteral feeding through nasogastric and nasojejunal tube in severe acute pancreatitis: a noninferiority randomized controlled trial. Pancreas 2012;41(1):153–9.
157. Chang YS, Fu HQ, Xiao YM, et al. Nasogastric or nasojejunal feeding in predicted severe acute pancreatitis: a meta-analysis. Crit Care 2013;17(3):R118.
158. Nally DM, Kelly EG, Clarke M, et al. Nasogastric nutrition is efficacious in severe acute pancreatitis: a systematic review and meta-analysis. Br J Nutr 2014;112(11):1769–78.
159. Guo YJ, Jing X, Tian ZB. Comparison of nasogastric feeding versus nasojejunal feeding for severe acute pancreatitis: a systematic review and meta-analysis. Int J Clin Exp Med 2016;9(11):22814–22823.
160. Zhu Y, Yin H, Zhang R, et al. Nasogastric nutrition versus nasojejunal nutrition in patients with severe acute pancreatitis: a meta-analysis of randomized controlled trials. Gastroenterol Res Pract 2016;2016:6430632.
161. Dutta AK, Goel A, Kirubakaran R, et al. Nasogastric versus nasojejunal tube feeding for severe acute pancreatitis. Cochrane Database Syst Rev. 2020;3(3):CD010582.
162. Lee PJ, Papachristou GI. Management of Severe Acute Pancreatitis. Curr Treat Options Gastroenterol. 2020:1–12.
163. Jacobson BC, Vander Vliet MB, Hughes MD, et al. A prospective, randomized trial of clear liquids versus low-fat solid diet as the initial meal in mild acute pancreatitis. Clin Gastroenterol Hepatol 2007;5(8):946–951.
164. Moraes JM, Felga GE, Chebli LA, et al. A full solid diet as the initial meal in mild acute pancreatitis is safe and result in a shorter length of hospitalization: results from a prospective, randomized, controlled, double-blind clinical trial. J Clin Gastroenterol 2010;44(7):517–522.
165. Meng WB, Li X, Li YM, et al. Three initial diets for management of mild acute pancreatitis: A meta-analysis. World J Gastroenterol 2011;17(37):4235–4241.

166. Rajkumar N, Karthikeyan VS, Ali SM, et al. Clear liquid diet vs soft diet as the initial meal in patients with mild acute pancreatitis: a randomized interventional trial. Nutr Clin Pract. 2013;28(3):365–70.
167. Lariño-Noia J, Lindkvist B, Iglesias-García J, et al. Early and/or immediately full caloric diet versus standard refeeding in mild acute pancreatitis: a randomized open-label trial. Pancreatology 2014;14(3):167–173.
168. Gianotti L, Meier R, Lobo DN, et al. ESPEN Guidelines on parenteral nutrition: pancreas. Clin Nutr 2009;28(4):428–435.
169. Baron TH, DiMaio CJ, Wang AY, et al. American Gastroenterological Association Clinical Practice Update: Management of pancreatic necrosis. Gastroenterology. 2020;158(1):67–75.
170. Asrani V, Chang WK, Dong Z, et al. Glutamine supplementation in acute pancreatitis: a meta-analysis of randomized controlled trials. Pancreatology 2013;13(5):468–474.
171. Zhong X, Liang CP, Gong S. Intravenous glutamine for severe acute pancreatitis: A meta-analysis. World J Crit Care Med. 2013;2(1):4–8.
172. Barker LA, Gout BS, Crowe TC. Hospital malnutrition: prevalence, identification and impact on patients and the healthcare system. Int J Environ Res Public Health. 2011;8(2):514–527.
173. Cerantola Y, Grass F, Cristaudi A, et al. Perioperative nutrition in abdominal surgery: recommendations and reality. Gastroenterol Res Pract. 2011;2011:739347.
174. Culebras JM. Malnutrition in the twenty-first century: an epidemic affecting surgical outcome. Surg Infect (Larchmt). 2013;14(3):237–243.
175. Leandro-Merhi VA, de Aquino JL. Determinants of malnutrition and post-operative complications in hospitalized surgical patients. J Health Popul Nutr. 2014;32(3):400–410.
176. Inciong JFB, Chaudhary A, Hsu HS, et al. Hospital malnutrition in northeast and southeast Asia: A systematic literature review. Clin Nutr ESPEN. 2020;39:30–45.
177. Braga M, Ljungqvist O, Soeters P, et al. ESPEN guidelines on parenteral nutrition: surgery. Clin Nutr. 2009;28(4):378–86.
178. Abunnaja S, Cuviello A, Sanchez JA. Enteral and parenteral nutrition in the perioperative period: state of the art. Nutrients. 2013;5(2):608–623.
179. Weimann A, Braga M, Carli F, et al. ESPEN guideline: Clinical nutrition in surgery. Clin Nutr. 2017;36(3):623–650.
180. Worthington P, Balint J, Bechtold M, et al. When is parenteral nutrition appropriate? JPEN J Parenter Enteral Nutr. 2017;41(3):324–377.
181. Lakananurak N, Gramlich L. The role of preoperative parenteral nutrition. Nutrients. 2020 6;12(5):1320.
182. Ward N. Nutrition support to patients undergoing gastrointestinal surgery. Nutr. J. 2003;2:18.
183. Klein S, Kinney J, Jeejeebhoy K, et al. Nutrition support in clinical practice: review of published data and recommendations for future research directions. Clin Nutr 1997;16:193.
184. de-Aguilar-Nascimento JE, Salomão AB, Waitzberg DL, et al. ACERTO guidelines of perioperative nutritional interventions in elective general surgery. Rev. Col. Bras. Cir. [online]. 2017;44(6):633–648.
185. Wischmeyer PE, Carli F, Evans DC, et al. Perioperative Quality Initiative (POQI) 2 Workgroup. American society for enhanced recovery and perioperative quality initiative joint consensus statement on nutrition screening and therapy within a surgical enhanced recovery pathway. Anesth Analg. 2018;126(6):1883–1895.
186. Lobo DN, Gianotti L, Adiamah A, et al. Perioperative nutrition: Recommendations from the ESPEN expert group. Clin Nutr. 2020;39(11):3211–3227.
187. Doig GS, Simpson F, Sweetman EA, et al. Early PN Investigators of the ANZICS Clinical Trials Group. Early parenteral nutrition in critically ill patients with short-term relative contraindications to early enteral nutrition: a randomized controlled trial. JAMA. 2013;309(20):2130–8.
188. Mete B, Pehlivan E, Gülbaş G, et al. Prevalence of malnutrition in COPD and its relationship with the parameters related to disease severity. Int J Chron Obstruct Pulmon Dis. 2018;13:3307–3312.
189. Ting HYT, Chan SHY, Luk EKH, et al. Prevalence of malnutrition in COPD inpatients and its relationship with nutritional intakes and clinical outcomes. J Aging Sci. 2020;8(1):219.
190. Steer J, Norman E, Gibson G, et al. P117 Comparison of indices of nutritional status in prediction of in-hospital mortality and early readmission of patients with acute exacerbations of COPD. Thorax. 2010;65(4):A127.
191. Hoong JM, Ferguson M, Hukins C, et al. Economic and operational burden associated with malnutrition in COPD. Clinical Nutrition. 2017;36(4):1105–1109.
192. Elia M. The cost of malnutrition in England and potential cost savings from nutritional interventions (full report). BAPEN. 2015.
193. Holdoway A, Anderson L, Banner J et al. Managing malnutrition in COPD. 2nd ed. 2020. Available at: www.malnutritionpathway.co.uk/copd.
194. Schols AM. Nutrition in chronic obstructive pulmonary disease. Curr Opin Pulm Med. 2000;6(2):110–5.
195. Dias CM, Pássaro CP, Cagido VR, et al. Effects of undernutrition on respiratory mechanics and lung parenchyma remodeling. J Appl Physiol (1985). 2004;97(5):1888–96.
196. Gea J, Sancho-Muñoz A, Chalela R. Nutritional status and muscle dysfunction in chronic respiratory diseases: stable phase versus acute exacerbations. J Thorac Dis. 2018;10(12):S1332–S1354.
197. Wilson DO, Rogers RM. The role of nutrition in weaning from mechanical ventilation. Journal of Intensive Care Medicine. 1989;4(3):124–133.
198. Rodríguez L, Cervantes E, Ortiz R. Malnutrition and gastrointestinal and respiratory infections in children: a public health problem. Int J Environ Res Public Health. 2011;8(4):1174–1205.

199. Nguyen HT, Collins PF, Pavey TG, et al. Nutritional status, dietary intake, and health-related quality of life in outpatients with COPD. Int J Chron Obstruct Pulmon Dis. 2019;14:215–226.
200. Guo Y, Zhang T, Wang Z, et al. Body mass index and mortality in chronic obstructive pulmonary disease: A dose-response meta-analysis. Medicine (Baltimore). 2016;95(28):e4225.
201. Ferreira IM, Brooks D, White J, et al. Nutritional supplementation for stable chronic obstructive pulmonary disease. Cochrane Database Syst Rev 2012;12:CD000998.
202. Collins PF, Stratton RJ, Elia M. Nutritional support in chronic obstructive pulmonary disease: a systematic review and meta-analysis. Am J Clin Nutr 2012;95(6):1385–1395.
203. Collins PF, Elia M, Stratton RJ. Nutritional support and functional capacity in chronic obstructive pulmonary disease: a systematic review and meta-analysis. Respirology 2013;18(4):616–629.
204. Naz I, Sahin H. The effect of nutritional support on pulmonary rehabilitation outcomes in COPD patients with low body mass index. Eur Resp J 2018;52.
205. Aldhahir AM, Rajeh AMA, Aldabayan YS, et al. Nutritional supplementation during pulmonary rehabilitation in COPD: A systematic review. Chron Respir Dis. 2020;17:1479973120904953.
206. Global strategy for diagnosis, management and prevention of COPD. The Global Initiative for Chronic Obstructive Lung Diseases (GOLD). 2020 report. Available from: https://goldcopd.org/gold-reports/.
207. Slinde F, Gronberg AM, Svantesson U, et al. Energy expenditure in chronic obstructive pulmonary diseaseevaluation of simple measures. Eur J Clin Nutr 2011;65(12):1309–1313.
208. Ganzoni A, Heilig P, Schonenberger K, et al. High-caloric nutrition in chronic obstructive lung disease. Schweiz Rundsch Med Prax 1994;83(1):13–6.
209. Baarends EM, Schols AM, Pannemans DL, et al. Total free living energy expenditure in patients with severe chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 1997;155(2):549–54.
210. Rondanelli M, Faliva MA, Peroni G, et al. Food pyramid for subjects with chronic obstructive pulmonary diseases. Int J Chron Obstruct Pulmon Dis. 2020;15:1435–1448.
211. de Batlle J, Sauleda J, Balcells E, et al. Association between Omega3 and Omega6 fatty acid intakes and serum inflammatory markers in COPD. J Nutr Biochem. 2012;23(7):817–21.
212. al-Saady NM, Blackmore CM, Bennett ED. High fat, low carbohydrate, enteral feeding lowers PaCO2 and reduces the period of ventilation in artifcially ventilated patients. Intensive Care Med. 1989;15(5):290–295.
213. Faramawy MA, Abd Allah A, El Batrawy S, et al. Impact of high fat low carbohydrate enteral feeding on weaning from mechanical ventilation. Egypt J Chest Dis Tuberc 2014;63(4):931–8.
214. Yartsev A. Nutritional manipulation of carbon dioxide production. Deranged Physiology February 27, 2016 https://derangedphysiology.com/main/required-reading/endocrinology-metabolism-and-nutrition/Chapter%205.1.4/nutritional-manipulation-carbon-dioxide-production.
215. Van den Berg B, Bogaard WCJ. High fat, low carbohydrate, enteral feeding in patients weaning from the ventilator. Intensive Care Med. 1994;20(7):479–475.
216. El Koofy NM, Rady HI, Abdallah SM, et al. The effect of high fat dietary modification and nutritional status on the outcome of critically ill ventilated children: single-center study. Korean J Pediatr. 2019;62(9):344–352.
217. Persson LJ, Aanerud M, Hiemstra PS, et al. Chronic obstructive pulmonary disease is associated with low levels of vitamin D. PLoS One. 2012;7(6):e38934.
218. Fernández-Lahera J, Romera D, Gómez Mendieta A, et al. Prevalence of vitamin D deficiency in patients with chronic obstructive pulmonary disease. Eur. Respir. J. 2015;46:PA3977.
219. Horadagoda C, Dinihan T, Roberts M, et al. Body composition and micronutrient deficiencies in patients with an acute exacerbation of chronic obstructive pulmonary disease. Intern Med J. 2017;47(9):1057–1063.
220. Ginde AA, Mansbach JM, Camargo CA Jr. Association between serum 25-hydroxyvitamin D level and upper respiratory tract infection in the Third National Health and Nutrition Examination Survey. Arch Intern Med. 2009;169(4):384–390.
221. Black PN, Scragg R. Relationship between serum 25-hydroxyvitamin D and pulmonary function in the third national health and nutrition examination survey. Chest. 2005;128(6):3792–3798.
222. Afzal S, Lange P, Bojesen SE, et al. Plasma 25-hydroxyvitamin D, lung function and risk of chronic obstructive pulmonary disease. Thorax. 2014;69(1):24–31.
223. Martineau AR, Jolliffe DA, Hooper RL, et al. Vitamin D supplementation to prevent acute respiratory tract infections: systematic review and meta-analysis of individual participant data. BMJ 2017;356:i6583.
224. Zendedel A, Gholami M, Anbari K, et al. Effects of vitamin D intake on FEV1 and COPD exacerbation: A randomized clinical trial study. Glob J Health Sci 2015;7(4):243–248.
225. Jolliffe DA, Greenberg L, Hooper RL, et al. Vitamin D to prevent exacerbations of COPD: systematic review and meta-analysis of individual participant data from randomised controlled trials. Thorax. 2019;74(4):337–345.
226. Nightingale J, Woodward JM. Guidelines for management of patients with a short bowel. Gut 2006;55(4):iv1–12.
227. Nguyen BT, Blatchford GJ, Thompson JS, et al. Should intestinal continuity be restored after massive intestinal resection? Am J Surg. 1989;158(6):577–579.
228. Messing B, Crenn P, Beau P, et al. Long-term survival and parenteral nutrition dependence in adult patients with the short bowel syndrome. Gastroenterology. 1999;117(5):1043–1050.

229. Marino IR, Lauro A. Surgeon's perspective on short bowel syndrome: Where are we? World J Transplant 2018;8(6):198–202.
230. Pironi L, Arends J, Bozzetti F, et al. Home artificial nutrition & chronic intestinal failure special interest group of ESPEN. ESPEN guidelines on chronic intestinal failure in adults. Clin Nutr. 2016;35(2):247–307.
231. Massironi S, Cavalcoli F, Rausa E, et al. Understanding short bowel syndrome: Current status and future perspectives. Dig Liver Dis. 2020;52(3):253–261.
232. Nightingale JM, Kamm MA, van der Sijp JR, et al. Gastrointestinal hormones in short bowel syndrome. Peptide YY may be the' colonic brake' to gastric emptying. Gut 1996;39(2):267–72.
233. Szczygiel B, Jonkers-Schuitema CF, Naber T. Basics in clinical nutrition: Nutritional support in extensive gut resections (short bowel). e-SPEN, Euro E-J Clinic Nutr Metab. 2010;5(1):e63–e68.
234. Kowlgi NG, Chhabra L. D-lactic acidosis: an underrecognized complication of short bowel syndrome. Gastroenterol Res Pract. 2015;2015:476215.
235. Johnson E, Vu L, Matarese LE. Bacteria, Bones, and Stones: Managing Complications of Short Bowel Syndrome. Nutr Clin Pract. 2018;33(4):454–466.
236. Yang J, Sun H, Wan S, et al. Risk factors for nephrolithiasis in adults with short bowel syndrome. Ann Nutr Metab 2019;75(1):47–54.
237. Hylander E, Jarnum S. Jensen HJ, et al. Enteric hyperoxaluria: dependence on small intestinal resection, colectomy, and steatorrhoea in chronic inflammatory bowel disease. Scand J Gastroenterol. 1978;13(5):577–588.
238. Parks JH, Worcester EM, R. Corey O'Connor RC, et al. Urine stone risk factors in nephrolithiasis patients with and without bowel disease. Kidney Int. 2003;63(1):255–65.
239. Amiot A, Messing B, Corcos O, et al. Determinants of home parenteral nutrition dependence and survival of 268 patients with non-malignant short bowel syndrome. Clin Nutr. 2013;32(3):368–74.
240. Joly F, Dray X, Corcos O, et al. Tube feeding improves intestinal absorption in short bowel syndrome patients. Gastroenterology 2009;136(3):824–31.
241. Pironi L, Sasdelli AS. Intestinal failure-associated liver disease. Clin Liver Dis 2019;23(2):279–91.
242. Lal S, Pironi L, Wanten G, et al. Home Artificial Nutrition & Chronic Intestinal Failure Special Interest Group of the European Society for Clinical Nutrition and Metabolism (ESPEN). Clinical approach to the management of Intestinal Failure Associated Liver Disease (IFALD) in adults: A position paper from the Home Artificial Nutrition and Chronic Intestinal Failure Special Interest Group of ESPEN. Clin Nutr. 2018;37(6 Pt A):1794–1797.
243. Wang C, Venick RS, Shew SB, et al. Long-term outcomes in children with intestinal failure-associated liver disease treated with 6 months of intravenous fish oil followed by resumption of intravenous soybean oil. JPEN J Parenter Enteral Nutr. 2019;43(6):708–716.
244. Lauro A, Lacaille F. Short bowel syndrome in children and adults: from rehabilitation to transplantation. Expert Rev Gastroenterol Hepatol. 2019;13(1):55–70.
245. Jeejeebhoy KN. Short bowel syndrome: a nutritional and medical approach. CMAJ. 2002;166(10):1297–1302.
246. Miranda SC, Ribeiro ML, Ferriolli E, et al. Hypomagnesemia in short bowel syndrome patients. Sao Paulo Medical Journal 2000;118(6):169–172.
247. Bielawska B, Allard JP. Parenteral nutrition and intestinal failure. Nutrients. 2017;9(5):466.
248. Olieman J, Kastelijn W. Nutritional feeding strategies in pediatric intestinal failure. Nutrients. 2020;12(1):177.