Nutrition Support for the Critically Ill, Post–Bariatric Surgery Patient
A Clinical Update

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The increase of bariatric surgery patients implies that more of them will present to intensive care units with altered gastrointestinal anatomy. Intensive care unit patients who have a history of recent or previous bariatric surgery comprise a unique population for conducting nutritional assessments and developing nutrition care plans. An assumption that such patients can automatically be assigned to guidelines intended for critically ill obese patients is problematic. Limited research exists to define appropriate nutrition support practice in the postbariatric population. This review provides an overview of bariatric surgical procedures with an emphasis on the sequelae of altered gastrointestinal anatomy, the evaluation of current evidence on providing nutrition support to critically ill patients who have a history of bariatric surgery, and to update clinical guidelines for delivering nutrition support to these patients. Key words: bariatric surgery, critical illness, enteral nutrition, nutrition support, obesity, parenteral nutrition

INCREASED numbers of bariatric surgical procedures imply that there will be more patients entering intensive care units (ICU) with altered gastrointestinal (GI) anatomy. The number of bariatric surgery procedures grew substantially every year from the mid-1990s until 2009, when they leveled off at about 220,000 per annum. Intensive care unit patients who have a history of recent or previous bariatric surgery comprise a unique population in terms of conducting a nutritional assessment and developing the nutrition care plan. Some of these patients may be obese or morbidly obese and have complications from their surgery. Others may be of normal weight with altered GI anatomy or underweight with malnutrition as a result of the new illness or excessive weight loss and nutrient deficiencies.

A descriptive study of 467 nutrition support professionals in 2007 found that of those who responded to a survey, 60% reported seeing 1 to 10 bariatric surgery patients with complications within the previous year. Twenty percent of the respondents stated that they had seen more than 20 such patients in the same time frame. Practitioners reported the perception that they were seeing greater numbers of postbariatric patients. Methods of nutrition assessment and intervention for critically ill, postbariatric patients varied broadly among practitioners and depended on the individual practitioner’s clinical judgment.
The postbariatric population is likely to present with obesity. However, for some patients with a distant history of bariatric surgery, body mass index may be normal. A subset of postbariatric patients may be underweight and/or have developed malnutrition. For all patients with a history of bariatric surgery, altered GI anatomy must be considered when providing nutritional care. Bariatric surgery patients who have undergone malabsorptive procedures retain a risk for nutrient deficiencies that may become severe. Many of the long-term metabolic, hormonal, and physical effects of bariatric surgery remain unknown, although long-term data are accumulating. The purpose of this review is to provide an overview of bariatric surgical procedures, to discuss sequelae of altered GI anatomy, and to evaluate current evidence for critically ill patients who have undergone bariatric surgery.

SEARCH STRATEGY

The search of databases included PubMed and CINAHL. Inclusion criteria included randomized controlled trials, clinical trials, observational studies, descriptive studies, systematic reviews, and meta-analyses published in English within the past 10 years; however, older studies were considered if deemed relevant to the review. The population included adults 19 years of age or older, with a distant or recent history of bariatric surgery. Care settings were critical care and home care. The nutrition intervention studied was nutrition support. A total of 126 articles were identified initially through database searches. Following a review of article abstracts, 8 articles were found to address the topic directly. One additional article was identified by a reviewer recommendation.

While literature is available regarding complications of bariatric surgery and the critically ill patient with obesity, little research is focused on critical illness in patients with a distant or recent history of bariatric surgery. No randomized controlled trials were located that addressed this topic. The identified articles include 1 retrospective cohort study, 1 descriptive study, 2 consensus documents, and 5 narrative reviews. Although this review is narrative, every effort was made to select studies that reflect the current state of knowledge regarding the topic. Table 1 lists studies identified via the literature search.

BARIATRIC SURGERY UPDATE

Bariatric surgical procedures fall into 3 major categories: (1) malabsorptive, (2) restrictive, and (3) combination, that is, both restrictive and malabsorptive. Most bariatric surgical procedures are not considered experimental; the history of GI surgery for the purposes of promoting weight loss now stretches back nearly 60 years. Bariatric surgery is supported by an increasing amount of long-term data regarding effectiveness and safety. During the past decade, efforts have increased to accumulate data for the purpose of defining evidence-based guidelines and best clinical practices in bariatric surgery. The Bariatric Outcomes Longitudinal Database is a proprietary database that has existed since 2007. Established by the Surgical Review Corporation, the Bariatric Outcomes Longitudinal Database currently houses data for more than 500,000 bariatric surgery patients worldwide. The Bariatric Outcomes Longitudinal Database is used to establish quality benchmarks for bariatric surgical procedures and to establish standards by which surgical centers may be designated Bariatric Centers of Excellence.

Four bariatric surgical methods are illustrated in the Figure. Worldwide, the most common bariatric surgery is the laparoscopically placed adjustable gastric band (AGB) (see the Figure). A purely restrictive procedure, the AGB induces weight loss by limiting the size of the gastric pouch and thus reducing the amount of food that can be consumed. The stomach and the lower GI tract remain intact, and the pathway of food through the digestive system remains unchanged. Repeated operations are common,
### Table 1. Nutrition Support Post-Bariatric Surgery

<table>
<thead>
<tr>
<th>Table of Studies Identified Via Literature Search</th>
<th>Type of Study</th>
<th>Methods</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choban et al&lt;sup&gt;49&lt;/sup&gt;</td>
<td>Consensus guidelines</td>
<td>Systematic review of evidence</td>
<td>Provides guidelines, on the basis of available evidence, for nutrition care of hospitalized adults with obesity.</td>
</tr>
<tr>
<td>Fujioka et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Narrative review</td>
<td>N/A</td>
<td>Describes nutrition problems that may occur in hospitalized and critically ill patients following bariatric surgery.</td>
</tr>
<tr>
<td>Hamilton et al&lt;sup&gt;63&lt;/sup&gt;</td>
<td>Retrospective cohort</td>
<td>Retrospective chart review</td>
<td>Hypocaloric TPN maintained nutritional status while promoting weight loss in home care patients with complications of bariatric surgery.</td>
</tr>
<tr>
<td>Kumpf et al&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Descriptive</td>
<td>Questionnaire administered to 473 nutrition support professionals</td>
<td>467 practitioners indicated widely varying practices regarding the provision of nutrition support to critically ill, morbidly obese patients, thus supporting the need for the development of evidence-based practice guidelines.</td>
</tr>
<tr>
<td>Martindale et al&lt;sup&gt;54&lt;/sup&gt;</td>
<td>Narrative review</td>
<td>N/A</td>
<td>Provides suggestions for future research regarding critically ill, morbidly obese patients.</td>
</tr>
<tr>
<td>McClave et al&lt;sup&gt;15&lt;/sup&gt;</td>
<td>Consensus recommendations</td>
<td>N/A</td>
<td>Provides consensus recommendations for the nutrition care of critically ill, morbidly obese patients.</td>
</tr>
<tr>
<td>Segaran&lt;sup&gt;57&lt;/sup&gt;</td>
<td>Narrative review</td>
<td>N/A</td>
<td>Discusses issues surrounding the provision of nutrition support to obese, critically ill patients experiencing complications following bariatric surgery.</td>
</tr>
<tr>
<td>Shah&lt;sup&gt;22&lt;/sup&gt;</td>
<td>Narrative review</td>
<td>N/A</td>
<td>Discusses the provision of nutrients to patients who become ill postsurgically; describes the provision of nutrients through the remnant stomach.</td>
</tr>
<tr>
<td>Ziegler et al&lt;sup&gt;62&lt;/sup&gt;</td>
<td>Narrative review</td>
<td>N/A</td>
<td>Provides update on long-term follow-up of nutrition issues in post-bariatric patients.</td>
</tr>
</tbody>
</table>

Abbreviations: N/A, not applicable; TPN, total parenteral nutrition.
since the gastric band may become displaced or eroded. Typical weight losses resulting from successful AGB procedures average about 35% of excess weight, although a long-term failure rate of nearly 50% has been noted.\(^5\) Failure may be related to band-related complications or to consumption of amounts of food and/or nutrient-dense liquids large enough to stretch the stomach pouch.

Popularly known as the “gastric bypass,” the Roux-en-Y surgery is the most common bariatric procedure used in the United States (see the Figure). In this combination procedure, the proximal and distal portions of the stomach are surgically separated, and a stomach pouch of about 30 mL in volume is created.\(^10\) A loop of the jejunum (the “Roux limb”) is attached to the stomach pouch, and the biliopancreatic limb is attached to the Roux limb about 75 to 150 cm from the anastomosis of the stomach pouch and jejunum. The portion of intestine remaining below the anastomosis created below the Roux junction is called the “common channel.” Weight loss is induced both by the reduced size of the stomach pouch and by the malabsorption resulting from the intestinal resection.\(^3,\,5,\,6\) Long-term results have been described as 49% to 62% excess weight loss maintained over 5 to 14 years in about 85% of patients.\(^3,\,5\) Postsurgical complications such as dumping syndrome and macro- and micronutrient deficiencies are common, occurring in an estimated 70% of Roux-en-Y patients.\(^3\) However, in most cases, these complications are manageable with the use of nutrient supplementation and nutrition education regarding appropriate eating practices.\(^11\)

“Gastric sleeve” surgery has gained popularity in recent years. Gastric sleeve surgery is purely restrictive and involves removal of a substantial portion of the stomach, leaving a greatly reduced pouch (the “sleeve”) for digestive purposes (see the Figure). Gastric sleeve surgery may be used as part of a surgical sequence for high-risk patients; patients may receive the sleeve to promote initial weight loss and then receive a gastric bypass at a later time upon improvement of risk factors.\(^12\) Short-term data indicate that the gastric sleeve surgery may provide greater weight loss results and fewer complications than the AGB;

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**Figure.** Altered gastrointestinal anatomy resulting from 4 methods of bariatric surgery. Image courtesy of Walter Pories, MD. Reprinted with permission.
however, unlike gastric banding, the gastric sleeve surgery is not reversible. Compared with the Roux-en-Y gastric bypass, surgical complication rates are similar, and there are fewer serious nutritional complications.\textsuperscript{5,13,14}

The biliopancreatic diversion with duodenal switch is a combination surgery that became popular in the 1990s and then quickly fell from favor (see the Figure) Although the surgery results in slightly greater weight loss than the Roux-en-Y bypass, high rates of severe macro- and micronutrient deficiencies, surgical complications, and deaths have prompted many bariatric surgeons to abandon the procedure.\textsuperscript{6,15,16} Patients who have undergone biliopancreatic diversion with duodenal switch, however, may present with critical illness; thus, the clinician should be familiar with the anatomical alterations associated with the surgery.

At the current time, little is known regarding the long-term consequences of substantially altered GI anatomy and chronic malabsorption of nutrients.\textsuperscript{15} Data have indicated reductions in long-term mortality in patients receiving both gastric banding and gastric bypass surgical procedures.\textsuperscript{17} Short-term complication rates and weight loss results appear to be influenced by the skill of the bariatric surgeon, with the best results obtained by surgeons and facilities performing high volumes of bariatric surgical procedures.\textsuperscript{3,16,18} As long-term data continue to accumulate, it is expected that knowledge will increase regarding outcomes of bariatric surgery over the life span.

**POSTOPERATIVE COMPLICATIONS OF BARIATRIC SURGERY**

**Nutrition-related**

Common nutrition complications of bariatric surgery include both macro- and micronutrient deficiencies. The overall nutrition-related complication rate for patients undergoing bariatric surgery appears to be about 30\%, with numbers substantially higher for malabsorptive surgical procedures.\textsuperscript{19} Nutrition complications may occur because of alterations in the size and length of the stomach and the intestines, reduction of surface area for nutrient absorption, reduced numbers of metabolites necessary for nutrient absorption such as intrinsic factor or gastric acid, and/or alterations in dietary consumption patterns.

**Macronutrient deficiencies**

Little is known regarding long-term patterns of dietary consumption following bariatric surgery.\textsuperscript{20} However, it seems apparent that a substantial decrease in total consumption of macronutrients occurs, whether or not percentage intake of macronutrients is altered following surgery. A systematic review of dietary intake following AGB surgery found that although proportional protein intake as part of total dietary intake is maintained or slightly increased, total protein consumption in grams is decreased.\textsuperscript{20} The same review reported the likelihood of a moderate decrease in percent fat intake and a concurrent increase in percent carbohydrate intake among the same population.\textsuperscript{20} Moizé et al\textsuperscript{21} studied a cohort of patients who had undergone either sleeve gastrectomy or Roux-en-Y gastric bypass and found no long-term changes in percent macronutrient intake for either group. It should be noted that the population was Spanish, and macronutrient proportions were compared with those identified for the general Spanish population.\textsuperscript{21} The cohort’s total nutrient intake decreased significantly, with total energy intake but not macronutrient distribution predicting percent weight loss.\textsuperscript{21} Analysis of typical food consumption patterns is an important component of a complete nutrition assessment for post-bariatric patients, although this information may be difficult to obtain in the critical care setting.

Protein deficiency is the most common macronutrient deficit following bariatric surgery, and, if severe, can result in a diagnosis of protein-energy malnutrition.\textsuperscript{19,22} Possible causes of protein-energy malnutrition include reduced oral intake and/or surgical complications resulting in too much or too
rapid weight loss. The small stomach pouch remaining after a gastric resection may produce insufficient stomach acid to promote normal protein digestion.\textsuperscript{22} Enteral nutrition or reversal of the surgery may be required in extreme cases.\textsuperscript{19,22}

Bariatric surgery can result in fat malabsorption with resultant steatorrhea and other metabolic complications.\textsuperscript{23,24} One study of 9 patients before and after Roux-en-Y gastric bypass surgery found a significant reduction in fat absorption ($P < .001$) following bariatric surgery but no differences in fecal fat excretion pre- and postsurgery.\textsuperscript{24} The degree of fat malabsorption in Roux-en-Y patients appears to be associated with the length of the common channel below the anastomosis of the biliopancreatic and Roux limbs. According to Fujioka et al,\textsuperscript{19} a common channel length of 100 cm appears to be well tolerated in terms of postsurgical fat absorption capabilities. If fat malabsorption is severe, patients undergoing bariatric surgery may develop essential fatty acid deficiency, requiring parenteral administration of lipids or even reversal of the surgery.\textsuperscript{19}

Improvements in carbohydrate metabolism, including resolution of symptoms of diabetes, have been associated with bariatric surgery.\textsuperscript{25} Similar improvements in \(\beta\)-cell function and insulin sensitivity have occurred in both gastric bypass and AGB patients, suggesting that substantial weight loss is largely responsible for positive metabolic outcomes.\textsuperscript{26} Odstriel et al\textsuperscript{25} and Hammer and Hammer\textsuperscript{27} reported that indicators of carbohydrate absorption remained unchanged in a group of obese patients examined before and after Roux-en-Y gastric bypass surgery. Problems with carbohydrate-associated energy deficiency following surgery may be related to medical or surgical complications that preclude ingestion of adequate, albeit reduced, amounts of carbohydrates.

**Micronutrient deficiencies**

Micronutrient deficiencies following bariatric surgery can exacerbate or complicate the course of critical illness.\textsuperscript{15} Micronutrient deficiencies may be related to the length of absorptive surface area remaining after surgery.\textsuperscript{22} Depending on the specific portions of the digestive and absorptive surface areas that have been bypassed or reduced, a variety of macro- or micronutrient deficiencies may occur.

Moizé et al\textsuperscript{21} found that dietary intake of calcium, magnesium, phosphorus, and iron did not meet recommendations in a cohort of post–sleeve gastrectomy and post–Roux-en-Y gastric bypass patients. Other investigators have reported micronutrient deficiencies including the water-soluble vitamins thiamine, \(\text{B}_{12}\), folate, and \(\text{C}\), as well as the fat-soluble vitamins \(\text{D}, \text{A}, \text{and K}\).\textsuperscript{28} Commonly reported mineral deficiencies include iron, zinc, calcium, and copper\textsuperscript{28,29} however, altered digestion and absorption of virtually any micronutrient may occur following surgery. Physical and biochemical findings may indicate the presence of micronutrient deficiencies in postbariatric patients. Investigators have described a variety of nutritional aberrations, including zinc deficiency associated with acrodermatitis,\textsuperscript{30} iron deficiency associated with anemia,\textsuperscript{31} and vitamin A deficiency associated with low serum prealbumin.\textsuperscript{32} The mechanism underlying vitamin A deficiency and reduced levels of serum proteins such as prealbumin in bariatric patients remains poorly understood. Explanations proposed have included reduced food intake, reduced absorptive surface area in the small intestine, and effects associated with prealbumin’s role as a transporter of retinol-binding protein.\textsuperscript{32}

Moizé et al\textsuperscript{21} found 25-hydroxy vitamin D deficiency to be the most common micronutrient deficiency within a study group of more than 300 post–bariatric surgery patients. Similar to several other micronutrients, the precise location where vitamin D is absorbed in the intestine remains unknown, making the prediction of specific deficiencies in particular patients difficult.\textsuperscript{29} Thus, patients with a history of bariatric surgery should be monitored at regular intervals for overall nutritional status, including micronutrient status.\textsuperscript{28} The possibility of atypical micronutrient
deficiencies should not be dismissed when performing nutrition assessment in the postbariatric surgery population.

**Dumping syndrome**

Dumping syndrome is the most common nutrition-related problem experienced by Roux-en-Y gastric bypass patients, with approximately 50% to 70% of patients experiencing this symptom. The Roux-en-Y procedure promotes dumping syndrome by allowing for very rapid infusion of the reduced stomach’s contents into the jejunum, with subsequent forceful osmotic effects. During a dumping episode, a quick fluid shift occurs between the intravascular space and the lumen of the intestine. The early phase of dumping may include abdominal pain, nausea, cramping, and diarrhea. The late phase encompasses the effects of resultant hypoglycemia and may include sweating, palpitations, weakness, trembling, and even syncope.

Avoidance of foods such as simple carbohydrates, which may precipitate dumping, may be associated with weight loss. However, Shah and Banerjee et al recently reported that long-term weight loss following a Roux-en-Y procedure is associated with reduced food intake rather than with dumping syndrome. Dumping syndrome in severe cases may serve as an etiological factor in identified macro- and micronutrient deficiencies or protein-energy malnutrition. Dumping syndrome can usually be managed effectively by providing appropriate nutrition education to bariatric surgical patients. While dumping symptoms tend to lessen with the passage of time, refractory dumping symptoms may require medical or surgical intervention. Medical treatments may include the use of somatostatin analogs such as octreotide which has been demonstrated to be effective in ameliorating dumping symptoms. Surgical treatment may include anatomical revisions designed to slow down the speed of gastric emptying. For patients who have received a Roux-en-Y procedure, insertion of an additional length of jejunum between the stomach and the jejunal anastomosis may relieve dumping symptoms. Enteral feeding into the jejunum may be required if dumping symptoms cannot be resolved.

**Nausea and vomiting**

Nausea and vomiting in postbariatric surgery patients may be associated with consumption of portions too large for the reduced gastric pouch or by the simultaneous consumption of solids and liquids. Nausea and vomiting in the postbariatric surgery patient requires medical follow-up and further investigation, since this symptom may result from strictures or GI obstruction. The majority of cases of nausea and vomiting can be resolved with appropriate nutrition education. Mechanical causes of nausea and vomiting may require surgical treatment. Although uncommon in the critical care setting, pregnancy can be a cause of nausea and vomiting. Post–bariatric surgical patients who are pregnant should be carefully monitored for nutrient deficiencies and supplemented as needed on an individual basis.

**Surgery-related**

Surgical complications appear in approximately 10% to 16% of Roux-en-Y gastric bypass patients. Correction of surgical complications often requires additional surgery, and such patients may require care in an ICU for some period of time during their clinical course. Until the complications are resolved, patients may require nutrition support, since intake of nutrients by the oral route may be contraindicated. Surgical complications can include but are not limited to anastomotic leaks, wound infections, anastomotic strictures, and incisional hernias.

The most common surgical complication is the anastomotic leak, affecting 2% to 5% of Roux-en-Y bypass patients. Leaks occur most commonly at the gastrojejunal anastomosis, with leaks also occurring at the jejunoejunojunostomy site or at the gastric staple line. More severely obese patients tend to experience an increased number of complications. In a prospective, descriptive study of 3,018 Roux-en-Y gastric bypass
patients, Gonzalez et al\textsuperscript{38} found that 63 patients developed anastomotic leaks. Among these patients, 58 reoperations were required, with duration of nutrition support lasting from 2 to 12 weeks.\textsuperscript{37,38} Thirty percent of these patients were receiving some type of nutrition support at hospital discharge.\textsuperscript{37,38}

Anastomotic strictures represent a common surgical complication of bariatric surgery. In many cases, strictures can be corrected via single or repeated endoscopic dilatation procedures.\textsuperscript{40} Some strictures require further surgery to achieve resolution.\textsuperscript{40}

NUTRITION SUPPORT OF CRITICALLY ILL POST–BARIATRIC SURGERY PATIENTS

Several authors have noted a dearth of research and thus, a lack of evidence-based guidelines regarding nutrition support for critically ill, post-bariatric surgery patients.\textsuperscript{15,22,37,41} Little is known regarding nutrition assessment issues in this population. Published definitions of hypocaloric, high-protein feeding are not consistent, and the degree to which weight status interacts with the effects of altered GI anatomy in critical illness is poorly understood.

At the present time, resources available to practitioners caring for such patients include a limited amount of literature, consensus guidelines for obese patients, and clinical judgment. For patients with a recent history of bariatric surgery, some literature is available regarding treatment of various complications including nutrient deficiencies and nutrition impact sequelae such as dumping syndrome.

Nutrition support approaches will vary on the basis of the patient’s current weight status. Although a large number of post-bariatric patients will present with obesity, patients may be underweight, overweight, or normal weight. Morbid obesity may be fully or partially resolved in individual patients, and malnutrition may vary in degree and type. Nutrition support professionals must be prepared to provide individualized care to post-bariatric surgical patients on the basis of each patient’s particular situation, and clinical judgment based on practitioner experience assumes increased importance.

Goals of nutrition support

According to the American Society for Parenteral and Enteral Nutrition/Society of Critical Care Medicine (ASPEN/SCCM) guidelines (McClave et al\textsuperscript{42}), the goals for nutrition support in critically ill obese patients differ little from goals for normal weight patients: promotion of healing by modulating the stress response, prevention of oxidative cell injury, and optimization of the immune response.\textsuperscript{42} Avoidance of poor metabolic outcomes, which may include hyperglycemia, hepatic injury due to excessive lipogenesis from overfeeding and/or intravenous lipid delivery, and excessive CO$_2$ production associated with overfeeding, is also an appropriate goal for nutrition support in the critically ill population regardless of weight status.\textsuperscript{37}

For critically ill patients who are obese, goals of nutrition support may include reduction of fat mass with simultaneous preservation of lean tissue.\textsuperscript{15} Early enteral nutrition may be advantageous in promoting desired goals. Enteral nutrition is recommended as the preferred feeding route whenever possible. However, in the presence of contraindications to enteral feeding, parenteral nutrition may be used as the method of nutrient delivery.\textsuperscript{42,43}

Nutrition assessment

Sedation and mechanical ventilation, common in the critical care setting, may present barriers to history taking if the patient is unaccompanied by persons who can provide information. Consensus guidelines recommend that all bariatric patients carry with them a written description of their surgery and its resultant GI anatomy.\textsuperscript{15} Information regarding the magnitude and rate of the patient’s resultant weight loss should be gathered if possible.\textsuperscript{15} In assessing
post–bariatric patients, the nutrition practitioner should assume that apparently random or unrelated symptoms, such as heart failure, neurologic pathology, or GI distress, could be associated with micronutrient deficiencies.15,22,37

**Energy and protein needs**

Ideally, indirect calorimetry (IC) should be used to measure energy needs in the critically ill, post–bariatric surgery patient. However, not every patient is a suitable candidate for IC, and many hospitals lack equipment for performing IC. In the absence of IC, predictive equations must be used to estimate energy needs. Existing studies regarding energy needs in the critically ill obese patients do not account for altered GI anatomy resulting from bariatric surgery. Little is known regarding the effects of higher weight ranges on energy needs in critical illness. Ireton-Jones,44 in a classic article published in 1991, noted that the correlation between actual body weight and energy expenditure disappeared in patients with body mass index exceeding 60 kg/m², suggesting that the difficulty in determining appropriate energy provision in extremely obese patients increases with body size.

Alves et al15 found that although the Harris-Benedict equation using actual body weight and no stress factor provided the most accurate results in critically ill obese patients, the range of variability of the results was unacceptable. Anderegg et al46 found that the Harris-Benedict equation using adjusted body weight and a stress factor provided results within 10% of measured needs in 50% of a group of 36 obese, hospitalized adults. Consensus guidelines prepared by participants in an Obesity in Critical Care workshop sponsored by Nestle Healthcare Nutrition and published in the *Journal of Parenteral and Enteral Nutrition* recommend that energy be provided to critically ill, obese adults at 11 to 14 kcal/kg actual body weight or 22 to 25 kcal/kg ideal body weight (IBW).15 However, no predictive equation or guideline recommendation is specifically applicable to post–bariatric patients.15,42

Frankenfield et al37 did a comparative study and evaluated the accuracy of 8 different predictive equations in 202 critically ill patients. The study evaluated 3 versions of the Penn State equation (PSU) and found that the PSU(m) equation was accurate within 10% of measured resting metabolic rate needs in 70% of young obese and 53% of elderly obese patients.37,47 More recently, Frankenfield48 used an expanded sample to validate the PSU(m) in adults older than 60 years, with body mass index greater than 30, finding accuracy within 10% of measured resting metabolic rate in 74% of patients. In ASPEN clinical guidelines for hospitalized obese adult patients published in 2013, Choban et al49 recommended that the 2010 PSU equation be used to estimate energy needs in hospitalized obese patients, and that the PSU(m) be used to estimate energy needs in hospitalized obese patients older than 60 years.48 The recommendation for use of the PSUs is rated strong, with high evidence.49

Evidence of the appropriate amounts of protein to provide to the critically ill, post–bariatric surgery population is limited. Intervention studies that have examined the effects of exact amounts of protein tend to be small, older, and use the parenteral rather than enteral mode of feeding.50,51 Krieger et al52 found better preservation of lean body mass during energy restriction with the provision of at least 1.05 g/kg/d protein; however, this study was not conducted in critically ill patients. American Society for Parenteral and Enteral Nutrition/Society of Critical Care Medicine guidelines recommend the provision of 1.5 to 2.0 g/kg IBW protein to hospitalized, obese patients.42 Consensus guidelines for the severely obese, critically ill patient recommend the provision of more than 2.0 g/kg IBW to persons with classes I and II obesity and more than 2.5 g/kg IBW to persons with class III obesity.15 The consensus guidelines are not specific to post–bariatric surgery patients.
Enteral and parenteral nutrition

When a functional GI tract is available, enteral nutrition is the nutrition support method of choice. However, enteral nutrition may be contraindicated in obese, critically ill post–bariatric surgery patients on the basis of a non-functional GI tract, increased intra-abdominal pressure promoting an unacceptable risk of reflux or aspiration, or lack of ability to confirm correct nasogastric tube placement radiographically because of large body size or physical barriers such as an extremely large pannus. In the case of morbidly obese patients, difficulty in reaching parts of the patient's body to provide care may necessitate the use of step stools or special lift teams and may hinder proper tube care and management.

Post–pyloric tube placement into the jejunum may be considered and may present fewer obstacles to achievement of nutritional goals than a gastric tube. Placement of a feeding tube into the remnant stomach has been successful in some post–bariatric surgical patients. In this case, food travels from the remnant stomach through the biliopancreatic limb and into the common channel via the jejunoojejunostomy located at the biliopancreatic limb/Roux limb anastomosis. If nutrition cannot be provided enteral, parenteral nutrition remains an option.

Hypocaloric, high-protein feeding

While a growing body of evidence indicates that the critically ill obese population may benefit from hypocaloric, high-protein feedings, there are no standard definitions or specific administration guidelines for such feedings. Hypocaloric, high-protein feedings allow for a calorie deficit while maintaining nitrogen balance and have been associated with improved clinical outcomes such as reduced days on ventilator support, fewer infections, better glycemic control, and reduced length of ICU stay. The 2013 ASPEN clinical guidelines for nutrition support for hospitalized obese adult patients recommend a trial of hypocaloric feeding at 50% to 70% estimated needs, or less than 14 kcal/kg, in patients without serious renal or hepatic disease; the strength of the recommendation is weak, with low evidence. The guidelines recommend the provision of protein at 1.2 g/kg actual body weight, or 2 to 2.5 g/kg IBW, with subsequent monitoring and adjustment of protein intake as indicated by nitrogen balance tests. Consensus recommendations for energy provision to critically ill, obese adults tend to approximate the recommended hypocaloric amount (11-14 kcal/kg actual body weight or 22-25 kcal/kg IBW).

Enteral formula

No specific guidelines exist at the current time regarding the best enteral formula for critically ill, post–bariatric surgery patients. For the subset of critically ill, post–bariatric surgery patients who are obese, McClave et al and Martindale et al have proposed the design of a formula specifically to minimize the metabolic derangements associated with critical illness as an important topic for research. Such a formula would be high-protein, low-carbohydrate and would provide some marine fat content as an anti-inflammatory component. Other nutrients have been proposed for inclusion as well, including arginine, glutamine, selenium, and zinc, although evidence to support these proposals is weak and inconclusive.

Micronutrient concerns

While a complete discussion of micronutrient needs for post–bariatric surgery patients is outside the scope of this article, it is important to remember that such deficiencies are common and may be present in a critically ill patient. In the critically ill, post–bariatric surgery patient, a strong possibility of surgically induced micronutrient deficiency should be assumed, especially if the patient has a history of the biliopancreatic diversion with duodenal switch or a Roux-en-Y gastric bypass. If possible, the patient should be questioned regarding compliance with ongoing nutrient supplementation.
Manzanares and Hardy\textsuperscript{55} reported that severe thiamin deficiency is common in the critically ill population and is associated with as much as a 50\% increase in overall mortality. McClave et al\textsuperscript{15} recommends intravenous thiamine administration in critically ill obese patients before providing dextrose solutions to prevent cardiac malfunction. Table 2 provides a list of symptomatic conditions along with possible related micronutrient deficiencies.

**Monitoring and refeeding syndrome**

Usual monitors of nutritional status applied to ICU patients should be used in the critically ill, obese population, including post–bariatric surgery patients.\textsuperscript{15} For obese patients, special attention may be paid to records of intake and output to ensure delivery of appropriate amounts of feeding. Serial measures of IC may be taken to monitor changing energy needs as fat mass is reduced.\textsuperscript{15} Monitors should also include micronutrient status, glycemic indicators, and measures of kidney function in view of high-protein feedings.\textsuperscript{15, 42, 45}

Regardless of weight status, the critically ill, post–bariatric surgery population may present with significant malnutrition and an increased risk for refeeding syndrome.\textsuperscript{56, 57} Refeeding syndrome is a potentially life-threatening complication most often associated with aggressive parenteral nutrition, but the condition may occur with enteral and oral feedings as well.\textsuperscript{58} Severe malnutrition is accompanied by suboptimal concentrations of intracellular electrolytes, as well as reduced secretion of insulin.\textsuperscript{57} During the process of refeeding, insulin secretion increases, resulting in rapid shifts of glucose, potassium, phosphate, magnesium, and water toward the intracellular space. Serum electrolyte abnormalities, including hypokalemia, hypophosphatemia, and hypomagnesemia, may precipitate severe sequelae such as cardiac arrhythmias, respiratory difficulties, and neurological aberrations.\textsuperscript{57}

Marik and Bedigian,\textsuperscript{59} in a study of 62 critically ill patients, found that refeeding syndrome occurred in 34\% of patients, and that the manifestations of refeeding syndrome can occur after as little as 48 hours of fasting. In the study by Marik et al,\textsuperscript{59} increased length of stay, as well as increased time to respirator weaning, was linked to the presence of refeeding syndrome as measured by serum phosphate levels. Rio et al\textsuperscript{60} studied a cohort of 243 hospitalized subjects receiving nutrition support for the first time. Rio et al\textsuperscript{60} found that risk factors associated with refeeding syndrome included poor dietary intake for more than 10 days, weight loss greater than 15\% prior to study initiation, and baseline hypomagnesemia. Hypomagnesemia at baseline was an independent predictor of refeeding syndrome ($P < .02$). Of the cohort, 133 presented with risk factors for refeeding syndrome, and 2\% of patients developed severe metabolic aberrations. Twenty-eight percent of patients died during hospitalization, but none of the deaths was directly linked to refeeding syndrome.\textsuperscript{60}

**Table 2. Conditions Associated With Micronutrient Deficiencies**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Possible Micronutrient Deficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anemia (macro- or microcytic)\textsuperscript{19, 22, 57}</td>
<td>Iron, B\textsubscript{12}, folate, Vitamin D, copper, zinc, Vitamin A, Vitamin E</td>
</tr>
<tr>
<td>Bone pathology\textsuperscript{19}</td>
<td>Calcium, Vitamin D</td>
</tr>
<tr>
<td>Heart failure\textsuperscript{15}</td>
<td>Thiamin</td>
</tr>
<tr>
<td>Neurological symptoms\textsuperscript{15, 22}</td>
<td>Thiamin, B\textsubscript{12}, Vitamin E, copper</td>
</tr>
<tr>
<td>Skin pathology\textsuperscript{19}</td>
<td>Vitamin A, zinc</td>
</tr>
<tr>
<td>Vision problems\textsuperscript{19}</td>
<td>Vitamin A, thiamin, Vitamin E</td>
</tr>
<tr>
<td>Idiopathic symptoms\textsuperscript{15}</td>
<td>Variable (nonspecific symptoms require further investigation)</td>
</tr>
</tbody>
</table>
In providing nutrition support to critically ill post–bariatric surgery patients, risk factors for refeeding syndrome should be assessed. Slow initiation of feeding coupled with careful monitoring and correction of electrolyte abnormalities during the refeeding process may prevent metabolic complications associated with the refeeding syndrome (Table 3).

Little research exists regarding the process of transitioning critically ill patients with a history of bariatric surgery from nutrition support to oral feedings. In practice, it appears that patients are often returned either to the first phase of the post–bariatric surgery diet (clear liquids) or to the type of diet the patient was consuming prior to critical illness. Benchmarks for oral intake before discontinuing nutrition support vary among institutions, but it appears that many institutions consider an oral intake of 50% to 60% estimated needs to be sufficient for termination of nutrition support.

**(CONCLUSION)**

At the present time, little evidence from sufficiently powered randomized controlled trials exists to inform the practice of nutrition support in critically ill patients with a recent or distant history of bariatric surgery.

An assumption that such patients can automatically be assigned to guidelines intended for critically ill obese patients is problematic. Not all post–bariatric surgery patients are obese. The amount and absorptive capacity of unaltered GI surface area differs from patient to patient. The range of macro- and micronutrient deficiencies that present in post–bariatric surgery patients, coupled with substantial variations in postsurgical GI anatomy, requires an individualized approach to each patient’s situation.

Every aspect of nutrition support to critically ill post–bariatric surgery patients requires further research to support the

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**Table 3. Suggestions for Providing Nutrition Support to Critically Ill, Post–Bariatric Surgery Patients**

| When performing nutrition assessment: |
| Gather relevant information regarding the patient’s surgery: |
| - Time elapsed since surgery |
| - Rate and magnitude of weight loss |
| - Weight history since surgery |
| - Nature of the patient’s altered GI anatomy |
| - Previous complications |
| Consider the possibility of nutrient deficiencies |
| Consider the possibility of refeeding syndrome in malnourished patients |

| When determining energy requirements: |
| Measure by indirect calorimetry if possible |
| Predictive energy equations may be used if indirect calorimetry is not available |
| - For obese patients younger than 60 years, use the 2010 Penn State Equation |
| - For obese patients 60 years of age or older, use the modified Penn State Equation |

| When determining protein requirements: |
| BMI < 30: 1.2-2.0 g/kg actual body weight |
| BMI ≥ 30 ≤ 40: ≥ 2.0 g/kg ideal body weight; BMI > 40: ≥ 2.5 g/kg ideal body weight |

| When considering hypocaloric, high-protein feedings for obese patients: |
| Avoid in patients with significant renal or hepatic disease |
| Provide energy at 50%-70% estimated needs, or < 14 kcal/kg |
| Provide protein at 1.2 g/kg actual body weight, or 2.0-2.5 g/kg ideal body weight |

Abbreviations: BMI, body mass index; GI, gastrointestinal.
development of evidence-based guidelines. Research focused on critical illness in such patients is a vital component for increasing the knowledge base regarding long-term outcomes of bariatric surgery, particularly as long-term data for various types of surgery continue to accrete.

Areas for future research include but are not limited to optimal provision of energy and protein, protocols for correction of nutrient deficiencies, best practices for nutrition support delivery, selection of appropriate enteral formulas, and delineation of optimal parameters for hypocaloric, high-protein feedings. Increased numbers of post-bariatric surgical patients ensure that issues for these patients in the critical care setting will remain an important component of daily practice for the nutrition support professional.

REFERENCES


