Nutritional Support in the Hospitalized Patient

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The approach to nutritional assessment and the delivery of nutrition support in the hospitalized patient has undergone a paradigm shift over the past decade. This shift has taken place as our perception of the incidence and definition of malnutrition, the role of the gastrointestinal (GI) tract, and reasons for providing nutritional support in the critical care setting have changed. In the past, nutritional support was provided solely for the prevention of protein energy malnutrition (PEM), an entity that was difficult to define. While older studies suggested that up to 50% of patients admitted to the hospital were either malnourished on admission or developed malnutrition during their hospital stay,1 more recently experts have been unable to agree on an accurate standardized definition of malnutrition. Clinical markers previously used to assess for PEM, such as anthropometrics, creatinine:height ratio, delayed cutaneous hypersensitivity, and serum visceral protein levels (albumin, prealbumin, and transferrin) have been shown to be inaccurate and to give an imprecise estimate of nutritional status.

With the current epidemic of obesity in the United States, where approximately two thirds of the population is either obese or overweight,2 most patients admitted to the hospital today will be obese. The true prevalence of malnutrition in hospitalized patients is probably less than 10%.3 Thus, while preventing deterioration of nutritional status is still a long-term goal of nutritional therapy, the more immediate focus early on in hospitalization (particularly with enteral feeding in critical care) is modulation of systemic immunity and attenuation of the stress response.

Previously, the GI tract was perceived to be a passive organ that was responsible simply for the digestion and absorption of exogenous nutrients, a function that was not considered vital or necessary when the patient developed severe critical illness. It is now known that the GI tract is the largest immune organ in the body, containing more than 65% of all immune tissue and producing more than 80% of secretory immune globulin.4,5 Thus, the gut plays a major role in the inflammatory response of various disease states. In addition, the gut is the major barrier to intestinal flora. Over a prolonged period of disuse, the GI tract undergoes structural and functional deterioration. Prolonged gut disuse, without enteral intake, results in atrophy of the intestinal villi and loss of mass of secretory IgA-producing immunocytes, regardless of whether the patient is on parenteral nutrition (PN).6 A major systemic injury followed by starvation results in an increase in gut permeability.7 Functionally, disuse of the gut results in decreased motility, bacterial overgrowth, inflammatory cytokine production, and diminished secretion of bile salts and secretory IgA, which inhibit adhesion of bacteria to the intestinal mucosa. Reduced contractility may result in a rapid rise in the population of intestinal bacteria. With both bacterial overgrowth and increased gut permeability, there is an increase in translocation of bacterial products and endotoxin across the mucosa. Under these conditions, bacteria engage the lymphoid tissue of the intestinal tract, which results in an upregulation of systemic immunity and a proinflammatory state. Not utilizing the GI tract may significantly exacerbate the initial insult and the overall disease severity of a critically ill patient.

With a better understanding of the gut’s role in critical illness, our understanding of the benefits of nutritional support has changed as well. In the past, nutritional support was considered adjunctive therapy, and the goal was to support the critically ill patient by reducing the degree of catabolism and the depletion of lean body mass in order to prevent PEM. Early enteral nutritional support in the appropriate setting now is regarded as a therapeutic tool used concurrently with other therapies to change clinical outcome. Instituting enteral nutrition (EN) early in the hospitalization of a
Critically ill patients will help maintain the barrier function and normal physiology of the GI tract. By maintaining gut integrity, EN modulates the immune response, thereby decreasing disease severity. In a recent meta-analysis, patients undergoing major surgery who received early postoperative EN had significant reductions in infection and hospital length of stay compared with patients who received no nutritional support. In a systematic review of patients in the intensive care unit (ICU), use of EN was associated with a significant reduction in infectious complications compared to use of PN. Providing early EN to the critically ill patient is associated with a trend toward reduced mortality compared with use of PN. Therefore, when nutritional support is indicated, EN is the preferred route of feeding in the critical care setting. The benefit of nutritional support changes with time. After 7 days, the ability to further modulate systemic immunity diminishes and the greater benefit of EN shifts to preventing deterioration of the patient’s nutritional status by providing sufficient calories and protein.

CASE PRESENTATION

A 62-year-old man with a past medical history of hypertension and diabetes mellitus presents to the emergency department with sudden onset of epigastric abdominal pain that began 2 days ago and is associated with nausea and vomiting. The patient has a history of excessive alcohol use. Physical examination shows a temperature of 100.5°F, pulse of 115 bpm, and blood pressure of 110/56 mm Hg. Significant findings include a distended abdomen with active bowel sounds and tenderness in the epigastric area. Pertinent laboratory values include a leukocyte count of 21,000/mm³, serum amylase concentration of 8860 U/L, lipase concentration of 16,420 U/L, and a normal composite metabolic profile (except for glucose level of 316 mg/dL). The patient is diagnosed with acute pancreatitis and started on intravenous fluid hydration and analgesia.

Over the next 12 hours, the patient’s condition deteriorates further with respiratory failure requiring mechanical ventilation and transfer to the ICU.

- What factors determine which patients should receive artificial nutritional support?

COMPONENTS OF NUTRITIONAL ASSESSMENT

Assessing Need for Nutritional Support

The first step in the nutritional assessment is determining whether the patient requires (and will most likely to benefit from) artificial nutritional support. The decision to initiate nutritional support in the ICU is based on the severity of illness, the degree of physiological stress, and the patient’s baseline nutritional status prior to injury. In general, normal well-nourished patients with a mild to moderate systemic injury or inflammatory insult can go 7 to 10 days without adequate nutritional intake. Patients who have an expected short duration of hospitalization and are nutritionally sound can be managed conservatively, allowing for volitional intake and oral nutritional supplements as indicated. Overall, the more critically ill the patient or the worse their baseline nutritional status, the greater the probability that they will require and benefit from early artificial enteral nutritional intervention.

Upon admission to the hospital, it is essential to assess the patient’s underlying nutritional state and the degree of disease severity. Estimating the amount of time the patient has gone without oral intake is an important factor in the initial decision to provide nutritional support. Correctly identifying patients who are significantly underweight or who have sustained substantial weight loss prior to the recent insult is important as these clinical signs are reliable indicators of a decline in nutritional status. Body mass index (BMI, defined as weight [kg]/height [m²]) can be used to identify patients who are at greater risk for adverse clinical outcomes as a result of poor nutritional status during the course of hospitalization. Patients with a BMI score less than 18 are considered to be mild to moderately malnourished.

For those who can provide a good history regarding recent changes in body weight, the amount of unintentional weight loss (classified as mild if < 5%, moderate 5% to 10%, or severe if > 10%) sustained over the 6 months prior to admission appears to be an additional indicator of adverse outcome related to deterioration of nutritional status. If a reliable history of weight loss cannot be obtained, a current actual body weight
less than 85% of ideal body weight serves as a clinical indicator of poor nutritional status. Certain patient populations are at increased risk for malnutrition, especially outpatients with an eating disorder, cancer, short gut syndrome, inflammatory bowel disease, or end-organ disease (eg, chronic obstructive pulmonary disease, cirrhosis, or renal failure). These patients more often will require artificial nutritional support over the course of hospitalization.

Overall disease severity can be reliably estimated with the use of standardized scoring systems, such as the APACHE (Acute Physiology and Chronic Health Evaluation) II score, Abdominal Trauma Index (ATI), and Ranson’s criteria. Higher scores (APACHE II ≥ 10, ATI ≥ 24, or ≥ 3 Ranson criteria) identify patients who are severely ill, who are at a higher risk for rapid decline in nutritional status, who are more likely to experience intolerance to oral diet or demonstrate poor volitional intake, and whose hospital course and clinical outcome are most likely to be favorably impacted by use of EN.14,15 These criteria should alert the clinician to the need for immediate artificial nutritional support. Good baseline nutritional status and lower standardized scores (APACHE II ≤ 9, ATI ≤ 23, or ≤ 2 Ranson criteria) identify patients with mild to moderate disease severity who do not need initial artificial nutritional support. Generally, artificial nutritional support in this group of patients is not considered unless the duration of the period of starvation persists beyond 7 to 10 days.

- **Would this patient benefit from artificial nutritional support?**

  The case patient had severe acute pancreatitis on admission, meeting more than 3 Ranson’s criteria, and he developed multiple organ system failure within 24 to 36 hours of hospitalization. Regardless of his baseline nutritional status, he is critically ill and would benefit from early initiation of artificial nutritional support with EN. A poor baseline nutritional status (eg, low BMI, history of significant weight loss) would further support the need for EN in this patient.

- **What are the next steps in the assessment of patients who require nutritional support?**

  Once a patient is correctly identified as qualifying for artificial nutritional support, the physician must take advantage of the optimal timing to provide support, evaluate for tolerance of EN, determine the route of feeding and level of infusion within the GI tract, choose the feeding tube, calculate daily caloric requirements, and select the type of formula to be used. In order to achieve its therapeutic endpoint and favorably impact patient outcome, EN should be started within 24 to 48 hours of admission to the hospital.

**Assessing Tolerance of EN**

Assessing overall function of the GI tract helps determine the likelihood for tolerance of enteral feeds. Contractility of the bowel is segmental in nature. Physical examination is used to detect evidence of dysmotility in the various sections of the GI tract. Delayed gastric emptying may be demonstrated by bloating, nausea, vomiting, increased gastric residual volumes, or high nasogastric output (> 1200 mL/24 hr). Colonic motility can be assessed by the passage of flatus or stool. Effective small bowel contractility is suggested by the presence of bowel sounds, but this physical finding is insensitive and may be diminished in patients with nasogastric tubes placed on intermittent suction. Significant abdominal distention and hyperresonance to percussion of the abdomen are signs of potentially poor small bowel contractility. Determining which segments are functional helps the physician select the appropriate feeding tube as well as the optimum level for infusion of formula within the GI tract (see discussion below).

The physician also must determine whether the infusion of enteral nutrients is safe from the standpoint of precipitating ischemic bowel and should evaluate the patient’s risk for aspiration of tube feeds. Provision of EN is not safe if there is potential for intestinal ischemia. Patients who are hypovolemic, septic, or hypotensive or those who require vasopressor support to maintain adequate blood pressure are at higher risk for gut ischemia after EN is initiated.16 EN may be given with caution to patients on chronic stable doses of vasopressor support, but EN should be withheld upon initiation of such therapy or in situations requiring escalating doses.

Part of the nutritional assessment of the critically ill patient being considered for EN involves an evaluation of potential risk factors for aspiration. The most common risk factors include the need for prolonged supine positioning, impaired level of consciousness, neuromuscular disease or structural abnormalities of the aerodigestive tract, age over 70 years, endotracheal intubation, history of severe gastroesophageal disease or gastroparesis, and presence of a nasoenteric feeding tube. If one or more of these factors is present, specific interventions should be made to decrease the likelihood for aspiration. However, determination that a patient is at significantly increased risk of aspiration...
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does not preclude use of EN in the ICU setting. Strategies to reduce the risk for aspiration include elevating the head of the bed greater than thirty degrees at all times, decreasing narcotic doses, initiating promotility agents, and providing good oral hygiene with a chlorhexidine mouthwash.

- If a patient is unable to tolerate EN or EN is not feasible, should PN be started?

While EN is always preferred over PN in critically ill patients, in certain circumstances where EN may not be feasible or safe, PN or standard therapy (without artificial nutritional support) is warranted. The decision whether to use PN and the optimum timing for initiation of such therapy is determined by the baseline nutritional status of the patient. In a well-nourished but critically ill patient not expected to resume oral intake soon, standard therapy is more efficacious than PN over the first 7 to 10 days of hospitalization. Over this time period, standard therapy is associated with significantly reduced infectious complications and length of hospital stay, with a trend toward reduced overall complications when compared to use of PN. After 7 to 10 days, continuing to provide standard therapy is associated with worse outcome, and initiating PN at this point in the hospital course is clearly associated with a decrease in the mortality rate. On the other hand, in patients with malnutrition (usually defined by weight loss > 10%–15%) for whom EN is not possible, priorities of subsequent therapy are reversed. PN is indicated for use in these patients over the first 7 to 10 days of hospitalization (when at least 7 days of therapy is anticipated) and is associated with better outcome than standard therapy over the same period.

Selecting the Feeding Tube

After determining that a patient is a candidate for EN, the next step is to select the appropriate tube for enteral feeding and determine the optimum level for infusion of formula within the GI tract. These decisions depend on the clinical prognosis, anticipated duration of feeding, overall function of the gut, risk for aspiration, and patient preference. More temporary short-term nasoenteric feeding tubes are placed in patients expected to require feeding for less than 4 weeks. These small, thin nasogastric or nasojejunal feeding tubes usually can be placed at the bedside with good success rates. Potential long-term complications of nasoenteric feeding tubes include nasopharyngeal erosions, pharyngitis, sinusitis, otitis media, and esophageal ulceration or stricture formation. For longer duration of artificial enteral nutritional support, a more permanent gastrostomy or jejunostomy tube may be placed radiographically, surgically, or endoscopically.

Patients with persistent nausea and vomiting, sustained high gastric residual volumes, a history of gastroparesis, documented aspiration, or evidence of partial gastric outlet obstruction should be considered for post-pyloric enteral feeding and placement of the feeding tube into the small bowel. Post-pyloric feeds may be accomplished by passing a nasoenteric tube into the distal duodenum or proximal jejunum, passing a small feeding tube through an existing percutaneous endoscopic gastrostomy (PEG) to create a percutaneous endoscopic gastrojejunostomy (PEGJ), or placing a direct percutaneous endoscopic jejunostomy (DPEJ) into the jejunum. Patients with severe acute pancreatitis usually require feeding directly into the jejunum to avoid stimulation of the pancreas.

Selecting a Formula

The enteral formulas available may be broadly categorized as polymeric, oligomeric or semi-elemental, immune-enhancing, and disease-specific. Polymeric formulas contain non-lactose carbohydrate, intact protein, and fat in the form of long-chain fatty acids. Oligomeric or semi-elemental formulas contain hydrolyzed protein in different lengths of small peptides or individual amino acids, and the majority of fat is in the form of medium-chain triglycerides. Elemental formulas, which are used less frequently, are nearly fat free (fat makes up < 2%–3% of the total calories) and are comprised of protein almost entirely in the form of individual amino acids. The dipeptides and tripeptides in the oligomeric formulas are more readily absorbed because specific transport mechanisms for small peptides on the intestinal mucosa are more efficient than the process of proteolysis and subsequent absorption of intact protein or the transport mechanisms required for each of the individual amino acids. Greater efficiency of absorption may promote greater assimilation in the compromised gut.

Immune-enhancing enteral formulas contain various proportions of immune-modulating agents, such as arginine, omega-3 fatty acids, glutamine, and antioxidants (selenium, vitamin C, vitamin E). While arginine plays a role in protein metabolism and nitrous oxide production, it acts as a direct immune stimulant by increasing lymphocyte and monocyte proliferation, increasing phagocytosis, and enhancing T-helper cell
function. Omega-3 fatty acids become incorporated into the cell membranes of immune-active cells, displacing the omega-6 fatty acids. When activated by the cyclooxygenase pathway, the leukotrienes and prostaglandins produced by the omega-3 fats have one tenth the biologic effect of those produced by omega-6 fat and thus exert an anti-inflammatory clinical effect.

Glutamine acts as a fuel for rapidly dividing cells, enhances immune cell function, helps maintain gut integrity, and has antioxidant properties. Antioxidants such as selenium, vitamin C, and vitamin E help scavenge oxygen free-radicals produced in critical illness, thereby decreasing cellular and tissue damage.

Disease-specific formulas are designed for patients with certain chronic disease states, such as diabetes, emphysema, cirrhosis, and renal failure. These formulas are generally more expensive, and there is little evidence in the literature indicating that their use improves patient outcome compared to use of standard formulas.

In selecting a formula suitable for a critically ill patient, the physician must first decide if that patient is a candidate for an immune-enhancing formula. Patients most likely to benefit from such a formula and experience improved outcomes are those with trauma (ATI > 20), burns (body surface > 30%), or head and neck cancer and those who are nonseptic but require mechanical ventilation. Two recent meta-analyses showed that use of immune-enhancing formulas is associated with significant reductions in infectious morbidity and length of hospital stay compared to use of standard enteral formulas. If patients do not meet these criteria, a standard polymeric formula should be used. Patients with prolonged gut disuse who are placed on a polymeric formula may develop signs of malabsorption and diarrhea; switching to a small-peptide formula should be considered.

### Table 1. Daily Energy Requirements

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caloric requirements</td>
<td>25–30 kcal/kg/day</td>
</tr>
<tr>
<td>Protein</td>
<td>1.2–1.5 g/kg/day</td>
</tr>
<tr>
<td>Free water</td>
<td>25–35 mL/kg/day</td>
</tr>
</tbody>
</table>

### Determining the Feeding Rate

After choosing the appropriate enteral formula, the physician must determine the rate or volume of enteral feeding to give based on daily energy requirements. Caloric requirements are best estimated by predictive equations based on body weight, such as 25 to 30 kcal/kg/day. More accurate methods for actually measuring caloric requirements involve indirect calorimetry or the metabolic cart. Protein requirements may also be calculated by simple equations. Critically ill patients usually require between 1.2 and 1.5 g/kg/day of protein based on actual body weight. Fluid volume or free water requirements can be estimated as 25 to 35 mL/kg/day. After subtracting out the volume of water contained in the formula, the remaining free water volume should be given in separate portions every 8 hours per the feeding tube for adequate hydration of the patient.

### CASE PRESENTATION CONTINUED

On the morning of his third hospital day, the patient has a nasojejunal feeding tube placed by endoscopy. A small-peptide formula is selected, and feeds are started at 25 mL/hr and gradually increased to a rate of 80 mL/hr over 24 hours.

- What is the recommended method of delivery of EN?

### MANAGING ENTERAL FEEDING

With the feeding tube in place and a formula chosen, the actual method of delivery of EN must be determined. In the critically ill patient, continuous infusion of enteral feeds is usually better tolerated and safer than bolus infusion because the risk for aspiration with continuous feeds is lower. Surprisingly, patients are more likely to tolerate rapid advancement of feedings rather than slow advancement, and the goal rate of infusion should be reached within 24 to 48 hours. Studies have suggested that at least 50% to 65% of the goal calories (ie, caloric requirements) must be delivered to achieve the clinical endpoints of EN (maintenance of gut integrity, prevention of increased peptides and medium-chain triglycerides is that it would be more readily absorbed. An immune-enhancing formula is a consideration if the patient does not have any underlying infections. A jejunal feeding tube is preferred for administering EN in patients with acute pancreatitis to decrease pancreatic exocrine secretion and reduce exacerbation of the disease process.
intestinal permeability, and attenuation of the stress response.\textsuperscript{27}

While many of the medications given in the ICU setting may be delivered via the feeding tube, attention should be paid to prevent clogging. The tube should be flushed regularly with 100 to 150 mL of water each 8-hour shift and with 30 to 40 mL of water after any medications are given. Liquid medications should be used whenever possible, and pills should be crushed thoroughly.

- What are the main causes for cessation of enteral feeds?

**CESSATION OF FEEDING**

Tube feedings are commonly stopped intermittently due to a variety of factors. In more than two thirds of cases, cessation of feeding occurs for unnecessary or inappropriate reasons.\textsuperscript{27} The most common reasons for cessation of EN include patient intolerance, high gastric residual volume (GRV), preparation for a procedure or diagnostic test, and displacement of the tube (Table 2).\textsuperscript{27} High GRVs lead to cessation of feeds in 15% to 17% of cases.\textsuperscript{27} GRVs are not a good indicator or marker for gastric emptying. GRVs ranging from 200 to 500 mL should increase concern for possible intolerance, but cessation of feeds should not occur in the absence of other signs of intolerance for volumes below 500 mL. In the majority of situations, an elevated GRV is an isolated event. Feeds should be continued after a single high GRV, as patients will have a second elevated GRV (within 4 hours of the first) only 20% of the time.\textsuperscript{27} High GRVs accompanied by nausea and vomiting, failure to pass flatus or stool, decreased bowel sounds, or abdominal distention indicate potential intolerance and that feeds may need to be stopped. Efforts to alleviate factors that contribute to ileus should be made, such as removing or reversing any medications that delay motility (eg, anticholinergics, opioid narcotics), maintaining blood glucose levels between 80 and 110 mg/dL, and correcting electrolytes to within normal range. If elevated GRVs persist after the above parameters have been addressed, then the infusion rate should be decreased or a trial of a prokinetic agent should be initiated. Additionally, placing the feeding tube lower in the GI tract and switching to post-pyloric infusion of feeding should be considered. Patients receiving post-pyloric feedings by a nasoenteric tube or a PEGJ should have aspirated residual volumes less than 10 to 20 mL. If residual volumes are higher, then an abdominal radiograph should be obtained to rule out migration of the tube back into the stomach.

Stopping all oral intake past midnight prior to surgery, a procedure, or a diagnostic test (nothing by mouth [NPO]) accounts for up to 40% of cases of unnecessary cessation of EN. Studies have shown that there are no significant differences in gastric volume or incidence of regurgitation between patients for whom feeds were stopped 4 hours prior to the procedure and patients kept NPO past midnight.\textsuperscript{28} Therefore, in the absence of signs of overt gastroparesis, infusion of enteral feeds should be continued up to 4 hours prior to a procedure or diagnostic test to increase the overall percentage of required calories infused.

Displacement of feeding tubes leads to cessation of EN in 5% to 15% of cases.\textsuperscript{26,27} Usually displacement occurs as a result of inadvertent removal of the feeding tube by nurses, ancillary staff, or the patient during daily routine patient care. Tube dislodgement may be averted at the time of initial placement of a nasoenteric tube by placing a nasal bridle. A “bridle” is made by placing a small feeding tube (such as a 5 French neonatal feeding tube) in one nares, around the nasal septum, and then out the other nares. The bridle then is taped to the feeding tube. Pulling on the feeding tube results in discomfort, which dissuades further efforts at dislodgement. For PEG tubes, abdominal binders that fit around the patient help secure the tube in the back, limiting patient access to the feeding tube. Commercial clipping devices with an adhesive bandage may be used to secure the PEG tube to the skin of the abdominal wall, reducing the chances for inadvertent removal.

**Table 2. Causes of Feeding Cessation**

<table>
<thead>
<tr>
<th>Cause</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient intolerance or persistent elevated gastric residual volumes</td>
<td>Discontinue antimotility medications</td>
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<tr>
<td></td>
<td>Control glucose (80–110 mg/dL)</td>
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<tr>
<td></td>
<td>Correct electrolytes</td>
</tr>
<tr>
<td></td>
<td>Consider prokinetic medications</td>
</tr>
<tr>
<td></td>
<td>Switch to post-pyloric EN delivery</td>
</tr>
<tr>
<td>NPO status for procedure or test</td>
<td>Stop feeds 4 hours prior to procedure/test</td>
</tr>
<tr>
<td>Tube displacement</td>
<td>Place a nasal bridle</td>
</tr>
<tr>
<td></td>
<td>Use an abdominal binder</td>
</tr>
<tr>
<td></td>
<td>Use clipping devices</td>
</tr>
</tbody>
</table>
Relative indications for cessation of feeds include hypotension requiring increased doses of vasopressors, hypoxemia, or impending cardiopulmonary arrest, as the risk of intestinal ischemia in these situations outweighs the benefit of the EN.

**CASE PRESENTATION CONTINUED**

The patient tolerates the feeds well without any complications until his seventh hospital day, when watery bowel movements develop.

- **What are the causes of diarrhea in patients receiving EN?**
- **What strategies can be employed to manage diarrhea in the critically ill patient on EN?**

**Management of Diarrhea**

Diarrhea is the most common GI complication of EN, with an estimated incidence ranging between 2% and 68%.²⁹–³² Because of varying definitions, the true incidence of diarrhea in these patients is unknown. A systematic approach should be taken in these patients because true diarrhea can lead to complications such as dehydration and breakdown of the skin. Diarrhea is more accurately defined by stool weight greater than 250 g/day, which helps to distinguish low-volume fecal incontinence from true diarrhea. The most common cause of diarrhea in patients receiving EN is related to medications. Prospective studies have shown that magnesium-based medications or sorbitol-containing elixirs are the cause of diarrhea in up to 50% of cases.³³,³⁴ Antibiotics alone increase risk for diarrhea in these patients either by altering the gut flora or by predisposing patients to *Clostridium difficile* infection. It is estimated that 20% of cases of diarrhea in critically ill patients on EN are due to *C. difficile* pseudomembranous colitis. Stool should be tested for both toxin A and B produced by this organism; if the toxin is present, appropriate antimicrobial treatment should be started. In approximately 20% of cases, the diarrhea may be related to intolerance of the formula. If diarrhea persists after the above possibilities have been excluded, switching to a small peptide formula or a fiber-containing formula may be appropriate. If diarrhea persists and infection has been ruled out, then antimotility agents (eg loperamide and diphenoxylate with atropine) can be given to decrease stool output.

**CASE CONCLUSION**

Testing for stool *C. difficile* toxin is positive, the patient is treated with a course of metronidazole, and the diarrhea resolves. The patient eventually makes a full recovery without requiring surgery. After 14 days, an oral diet is initiated and is tolerated without problems.

- **If this patient had been unable to tolerate EN, what strategies could have been implemented to maximize the efficacy and safety of the PN?**

**PARENTERAL NUTRITION**

PN is best administered through a large-bore venous catheter placed in a central vein. The optimum site for placement of a central catheter is the subclavian vein, but there is an increased risk for pneumothorax with this approach. Placement via the internal jugular vein is associated with greater patient discomfort and increased risk for infection compared with the subclavian route. Placement in the femoral vein decreases patient mobility and may have the highest risk for infection. While PN can also be administered through a peripheral vein, use of this route is discouraged because it promotes short-term duration (< 5–7 days) of parenteral feeding and increases risk for thrombophlebitis and venous sclerosis. Peripheral intravenous central catheters represent a sort of hybrid access device in that they are inserted peripherally into the brachial vein, but a long intravenous segment allows infusion of PN directly into the subclavian vein.

Appropriate ratios to use when calculating the composition of PN are 50% carbohydrate, 30% fat, and 20% protein. Electrolytes need to be monitored closely in patients receiving PN and adjusted accordingly to individual needs. Sodium and potassium should be given in a dose of 1 to 2 mEq/kg/d. Approximately 20 to 40 mEq of the total amount of anion provided with these cations should be given in the form of phosphate. The remaining amount of anion provided should be equally divided between acetate and chloride. An excess of acetate contributes to metabolic alkalosis, while too much chloride generates a metabolic acidosis. With all PN solutions, a standard preparation of multivitamins and trace elements should be given daily. Vitamin K may need to be added if it is not contained in the multivitamin solution.

Several strategies may be employed to promote greater efficacy and safety of PN. The provision of calories in excess of requirements to critically ill patients is associated with increased insulin resistance and infectious morbidity. Compared to EN, PN more frequently results in hyperglycemia and overfeeding only exacerbates this problem. In one study, hyperglycemia...
(glucose > 220 mg/dL) was shown to occur in over half of nondiabetic patients on PN when more than 35 kcal/kg/day was provided.\(^5\) For all patients receiving artificial nutritional support, particularly those on PN, strict glucose control is essential. In a landmark study involving ICU patients on nutritional support, patients randomized to strict glucose control (keeping glucose in the range of 80–110 mg/dL) had a reduced occurrence of sepsis and mortality compared with those randomized to conventional insulin therapy (resulting in a serum glucose range of 150–180 mg/dL).\(^6\) A standardized insulin protocol should be instituted and followed in all patients requiring artificial nutritional support. Along with tight glucose control, purposely giving a lower amount of calories (20 kcal/kg/d based on actual body weight) will assist with glucose control. The concept of “permissive underfeeding,” in which approximately 80% of caloric requirements are provided, helps to improve efficacy of PN while decreasing the probability of hyperglycemia, insulin resistance, and further complications. Studies have shown that early use of intravenous lipids may cause immunosuppression and adversely affect clinical outcome.\(^7,8\) Over the first 7 days, use of lipid-free PN is linked to a reduction in infectious morbidity and shorter hospital stay than use of lipid-containing PN. Use of lipid-free PN is safe for the short term (< 10 days) as the risk of essential fatty acid deficiency over this time period should be negligible.

**CONCLUSION**

Provision of enteral feeding to the critically ill patient is a valuable therapeutic modality that favorably impacts clinical outcome. Initial evaluation should focus on assessing the degree of critical illness, determining risk of aspiration, and calculating caloric requirements. Specific enteral formula, type of feeding tube, and level of infusion within the GI tract should be determined for each individual patient. PN should be reserved for very specific clinical situations where EN is not feasible. Once EN is initiated, patients should be monitored for tolerance, and strategic protocols should be implemented to ensure the infusion of a sufficient volume of feeds.

**REFERENCES**


TIME TO PREPARE

Candidates who meet the requirements of the
American Board of Internal Medicine
should apply for examination.

The 2006 subspecialty certification examination in gastroenterology is administered on
November 15, 2006.
Applications are accepted March 1 to May 1, 2006.
The 2006 subspecialty recertification examination in gastroenterology is on
May 17, 2006.
Applications are accepted December 1, 2005 to February 15, 2006.

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