Invited Review

Short Bowel Syndrome: Clinical Guidelines for Nutrition Management

Laura E. Matarese, MS, RD, LDN, FADA, CNSD*; Stephen J. O'Keefe, MD, MSc, FRCP†; Hossam M. Kandil, MD, PhD†; Geoffrey Bond, MD*; Guilherme Costa, MD*; and Kareem Abu-Elmagd, MD, PhD, FACS*

**Intestinal Rehabilitation and Transplant Center, Thomas E. Starzl Transplantation Institute, and the †Department of Gastroenterology, The University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania*

ABSTRACT: Intestinal failure is a condition in which inadequate digestion or absorption of fluid, electrolytes, and nutrients leads to dehydration or malnutrition. The most common cause of intestinal failure is short bowel syndrome (SBS) defined as <200 cm of functional small intestine. SBS may result from congenital abnormalities or from surgical resection. For the past 3 decades, patients with severe SBS were managed with home parenteral nutrition (HPN). With the emergence of new therapies, the clinician now has multiple options to treat these patients. These include intestinal rehabilitation regimens whereby patients are treated with specialized oral diets, soluble fiber, oral rehydration solutions (ORS), and trophic factors to enhance absorption. There are also a variety of surgical techniques available to preserve intestinal length. Small bowel and multivisceral transplantation has evolved during the last decade to be a valid therapeutic option for those patients who cannot be rehabilitated or who fail HPN. These are interrelated services designed to offer the patient the best therapeutic options to meet their individual needs. This article reviews the principles associated with the nutrition management of this very complex and diverse group of patients.

The normal small bowel length in adults ranges from 300 to 800 cm.[1] Loss of two-thirds or more of the small bowel is defined as short bowel syndrome (SBS).[2] SBS may result from congenital disorders (eg, intestinal atresia), surgical resection, or bypass of the intestine. In the United States, according to a 1995 epidemiologic report, there have been at least 20,000 adult patients with SBS receiving home parenteral nutrition (HPN) at an average annual cost of $150,000 per patient.[3] Although the number is small relative to other disease states, the level of care required by these patients is significant. In addition to the financial burden, long-term parenteral nutrition (PN) has been associated with numerous metabolic and septic complications[4,5] and diminished quality of life.[6] Nutrition is an integral component of the care of these very complex and heterogeneous patients and forms the foundation of treatment. Therapy options have expanded to include not only HPN but also intestinal rehabilitation programs designed to enhance absorption of the remnant bowel, surgical intestinal rehabilitation to prevent SBS, and intestinal transplantation when the bowel cannot be rehabilitated and the patient fails HPN. These are interrelated services designed to offer the patient the best therapeutic options to meet their individual needs. This article will review the principles associated with the nutrition management of this very complex and diverse group of patients.

Physiologic Consequences of Intestinal Resection

The primary physiologic consequence of SBS is malabsorption, resulting in fluid and electrolyte abnormalities and malnutrition. The severity of the malabsorption is determined by the extent and location of the resection, the presence or absence of the colon, the health of the remaining mucosa, and the ability of the remaining bowel to compensate, referred to as intestinal adaptation.[7] Fortunately, the small bowel has a large functional reserve capacity, and resections of <50% are generally well tolerated without requiring any significant intervention. Patients who have had a resection of 50%–70% will experience a transient malabsorption, which may require dietary modification, oral nutrition supplementation, and medications to enhance absorption and prolong transit time. When the extent of the

Correspondence: Laura E. Matarese, MS, RD, LDN, FADA, CNSD, Director of Nutrition, Intestinal Rehabilitation and Transplant Center, Thomas E. Starzl Transplantation Institute, UPMC Montefiore, 7 South, 3459 Fifth Avenue, Pittsburgh, PA 15213. Electronic mail may be sent to mataresele@upmc.edu.

0884-5336/05/2005-0493$03.00/0
Nutrition in Clinical Practice 20:493–502, October 2005

resection exceeds 75%, the patient will most likely develop significant malabsorption and require long-term PN or intestinal transplantation.

Aside from the length of bowel resected, the specific area of the surgical intervention influences absorption. Absorption of nutrients occurs throughout the small bowel, with the majority occurring in the first 150 cm.[8] Loss of the duodenum and terminal ileum will impair absorption more than loss of the jejunum. This is largely due to the specific absorptive and motility functions performed in these segments of bowel. Vitamin B_{12}-intrinsic factor is absorbed in the distal 100 cm of the ileum.[9] Therefore, patients with terminal ileal resections >60 cm will generally require vitamin B_{12} replacement. Absorption of bile salts occurs by specific receptors in the distal 100 cm of ileum, which are transported back to the liver through the portal vein and secreted again by the liver.[10] When <100 cm of terminal ileum is resected, unabsorbed bile salts are replaced by hepatic synthesis. Unfortunately, when the unabsorbed bile salts come in contact with the colonic mucosa, a secretory or cholerrheic diarrhea results. If >100 cm of the terminal ileum is removed, the bile salt pool cannot be maintained, because intestinal losses exceed the synthetic capacity of the liver. Steatorrhea tends to be severe, and secretory diarrhea can occur as a result of unabsorbed long-chain fatty acids coming into contact with the colon.[10]

The role of the ileocecal valve in enhancing absorption is not clear. The ileocecal valve is believed to be important in slowing transit by controlling the contents of the ileum into the cecum and preventing reflux of colonic contents into the small bowel.[11] This would allow increased contact time of luminal nutrients with the mucosal surface. It is also believed that the presence of the ileocecal valve decreases the risk of bacterial overgrowth in the small bowel by limiting reflux of the colonic contents. However, no changes in transit time or reflux have been observed in patients who have had ileocecal valve excision.[12,13]

Preservation of the colon is important for absorption of water, electrolytes, and fatty acids. It also plays a role in prolonging intestinal transit and stimulating intestinal adaptation. The ability of the patient to remain autonomous from HPN or IV fluids is not only dependent on the length of small bowel but also the presence or absence of the colon. Patients with <40–60 cm jejuno-ileum anastomosed to a portion of the colon or those with <100–140 cm small bowel and no colon will most likely require permanent long-term PN.[14–16] Those individuals with at least 150 cm ending in a stoma or 60–90 cm anastomosed to a portion or all of the colon can often be weaned from PN. The ability to wean patients is not only dependent on absolute bowel length but also enterocyte function.

Intestinal Adaptation

After surgical resection, the remaining bowel begins to increase absorptive function. The exact mechanism of mucosal adaptation in humans has not been fully elucidated. There is some evidence that the intestine hypertrophies and lengthens slightly with an increase in diameter and villus height.[17–20] However, a recent study by Ziegler et al[21] did not find evidence that adaptation involved hyperplasia of either the small bowel or colonic mucosa. Rather, an up-regulation of the peptide transporter PepT1 in the colon of patients with SBS was observed, suggesting that the colon can increase the luminal transport of di- and tripeptides derived from the diet or other sources. The exact time frame of the adaptation process is not known but generally thought to begin after surgery and continue for approximately 2 years.[22–25] This adaptive mucosal hyperplasia of the remnant bowel occurs only if nutrients are present in the intestinal lumen.[25] Luminal nutrients are the most potent stimulus to intestinal adaptation. Therefore, our practice is to transition patients to a complex diet as soon as possible.

Clinically, the patient with SBS progresses through several phases during the adaptation process. In the first phase (1–3 months), diarrhea is severe and absorption is limited. During this period, the patient requires full nutrient and fluid support with PN. The second phase of the adaptation process may last for a few months to 1 year. During this time, absorption improves and it may be necessary to begin reducing PN. Maximal adaptation is generally achieved by the second year. It is during this last phase that PN is reduced to several nights per week, or totally eliminated.

Evidence-Based Diet Modification for SBS

The exact dietary prescription should be based on the gastrointestinal (GI) anatomy of the patient. There are a limited number of studies that have evaluated the optimal composition of the diet for patients with SBS. Ovesen et al[26] compared the effect of a low-fat (30% kcal), high-complex-carbohydrate (55% kcal) diet with 2 high-fat (60% kcal), low-carbohydrate (25% kcal) diets in 5 stable patients with end jejunostomies (remnant bowel length range 35–125 cm beyond the ligament of Treitz). The 2 high-fat diets differed in their ratio of polyunsaturated/saturated fat (1:4 and 1:1). Neither the amount of fat nor the type of fat had any consistent influence on the volume of jejunostomy output or losses of sodium or potassium. However, the high-fat diet increased the loss of calcium, magnesium, copper, and zinc.

The optimal ratio of fat to carbohydrate was further evaluated in a small study of 8 patients with SBS.[27] The GI anatomy of the patients varied considerably. Length of small bowel ranged from 30 cm to approximately half of the small bowel, and 3 of

the 8 patients had remnant colon. The patients consumed, in random order for a 5-day period, either a high-fat (60% kcal), low-carbohydrate (20% kcal) diet or a high-carbohydrate (60% kcal) low-fat (20% kcal) diet. Both diets were lactose-free and low in fiber. Fluid intake was kept constant. There was no significant difference in stool or ostomy output; calorie absorption; zinc, calcium, or magnesium balance; urinary volume; or electrolyte excretion. The authors concluded that dietary restriction is not necessary for these patients.

The potential absorptive impact of the colon was acknowledged when Nordgaard[28] and colleagues compared the effects of modified diet in 16 patients with SBS. Ten of the patients had the colon in continuity and 6 patients had an end jejunostomy. Patients were randomized to receive either a high-carbohydrate, low-fat diet (60%:20% kcal) or a low carbohydrate, high-fat diet (20%:60% kcal) for 4 days. The protein content was held constant at 20% in each of the diets. Each patient acted as his or her own control and was crossed over from one diet to the other. Mineral output was not evaluated. For those patients with a retained colon, the high-carbohydrate, low-fat diet significantly reduced the fecal loss of calories compared with the high-fat, low-carbohydrate diet ($p = .0005$). Stool volume was not significantly different on either diet ($p > .05$). Fecal fat excretion was largely dependent on dietary intake and explained the differences in the fecal loss of energy, whereas the carbohydrate was nearly all absorbed and not influenced by intake. The authors suggested that nonabsorbed carbohydrate calories reaching the colon were fermented by colonic bacteria to short-chain fatty acids, absorbed, and then used for energy. For the patients with a jejunostomy, the changes in the diet made no difference in the percent of calories absorbed. However, the high-carbohydrate diet had a tendency to increase the stomal effluent by >700 mL per day compared with outputs on the high-fat diet. Although this was not statistically significant, a difference of 700 mL per day would most likely make a significant impact on the quality of life of a patient. Closer examination of the data reveals 3 of the 6 patients with jejunostomies experienced a reduction in effluent volume while they were receiving the low-carbohydrate, high-fat diet, whereas no differences were seen in the other 3 patients. The average daily stomal effluent of the patients with the jejunostomies was approximately 1.8 L per day more than the stool output of the patients with a colon in continuity. Thus, although altering the ratio of carbohydrate to fat did not seem to significantly influence caloric absorption in patients with jejunostomies, it appears that diet manipulation may be of value in the management of fluid and electrolyte losses, which is often the primary concern of such patients.

The largest clinical experience in attempting to optimize the diet was reported by Byrne and colleagues.[29] This was a prospective, randomized, placebo-controlled trial of 41 PN-dependent patients with SBS designed to evaluate the effects of recombinant growth hormone (rGH), glutamine (GLN), and diet on reducing PN requirements. Modified diet was used as a control in the study. Because most of the patients (n = 36) had a portion of the colon in circuit, 30% of the calories were supplied as fat, 50% as complex carbohydrate, and 20% as protein. The patients were supplied with 6–8 small meals and 1.5 L of oral rehydration solution (ORS). Although the intent of the study was to evaluate the effects of rGH, it was noted that the control group with optimized diet and GLN had a significant reduction in PN requirements over their baseline PN needs. The greatest reduction was seen in the group of patients who received the combined therapy of rGH, GLN, and modified diet.

The data on the role of diet modification for those patients without a colon are limited, and recommendations are often based on individual clinical experiences. It has been suggested that patients without a colon do not benefit from dietary modification and should be allowed to consume a diet *ad libitum*.[30] Others have suggested that because the proportion of fat absorbed in these patients is relatively constant,[27,31] an increase in oral intake could result in potentially greater energy absorption.[8] In treating more than 400 patients with SBS over the past decade, Byrne and colleagues[32] maintain that some of the patients without a colon still benefit from dietary intervention, as evidenced by decreased stool output and a positive enteral balance. Our own experience supports the use of modified diet in these patients to help control output and fluid losses.

Designing the Actual Diet Prescription

The goal of dietary management in patients with SBS is to diminish the symptoms associated with severe malabsorption while optimizing nutrient absorption so that reliance on specialized nonvolitional nutrition support can be minimized or eliminated. Complex oral nutrients should be provided as soon as possible in order to provide a stimulus to enhance intestinal adaptation. Enteral feeding by tube is generally not necessary unless the patient is unable to consume food by mouth. General dietary principles include providing small frequent meals consisting of complex foods according to GI anatomy (Table 1) in order to minimize GI symptoms.[33] Simple sugars (eg, disaccharides) should be avoided due to their tendency to increase the hyperosmotic load to the gut, which results in increased transit time and diarrhea. Increased stool or ostomy output should be controlled with the use of antidiarrheal and antisecretory agents (Table 2). As a group, patients with SBS are very heterogeneous and vary in terms of GI anatomy and health of remaining mucosa. Therefore, the diet prescription should be individualized for each patient in order to best meet the needs of the unique patient.

Table 1
Diet for SBS according to GI anatomy[33]

	Colon present	Colon absent
Carbohydrate	50%–60% of energy intake Complex carbohydrates Limit simple sugar	40%–50% of energy intake Complex carbohydrates Restrict simple sugar
Fat	20%–30% of energy intake Ensure adequate intake of essential fatty acids MCT/LCT	30%–40% of energy intake Ensure adequate intake of essential fatty acids LCT
Protein	20% of energy intake High biological value	20% of energy intake High biological value
Fiber	Soluble fiber for net secretors	Soluble fiber for net secretors
Oxalate	Restrict	No restriction necessary
Fluids	ORS or hypotonic as needed	ORS generally required

LCT, long-chain triglyceride; MCT, medium-chain triglyceride; ORS, oral rehydration solution; SBS, short bowel syndrome.

Energy

Energy absorption is variable in this patient population and largely dependent on length and health of remaining bowel. Depending on the extent of the resection and the degree of malabsorption, the patients may become hyperphagic and consume more than would be expected to be required to maintain nutrition autonomy.[34,35] These practices should be encouraged and the patient instructed on the best way to consume this additional food without increasing output, generally by consuming 5–6 small meals daily. Oral intake can also be supplemented with the use of slow, continuous, nocturnal enteral tube feeding.

Carbohydrate

The type of carbohydrate prescribed is essential in reducing abdominal cramping, flatulence, and ostomy output. The intake of concentrated simple sugars (eg, sucrose and fructose), especially in the form of fruit juices, should be minimized, as they produce a high osmotic load and tend to exacerbate the underlying osmotic diarrhea.[8,36] Complex carbohydrates such as those found in bread, pasta, potatoes, cereal, and rice are generally well tolerated and should comprise 50%–60% of energy intake. Those patients with a colon in circuit will derive added benefit from the fermentation of unabsorbed carbohydrates by colonic flora. Because the proximal

Table 2
Medications used to control output in short bowel syndrome

Antidiarrheal medications	
Loperamide HCl (2–4 mg)*	1–2 capsules/tablets PO 4 times per day (30–60 min AC and HS); increase as needed up to 8 capsules/tablets PO 4 times per day.
Diphenoxylate HCl (2.5–5 mg) and atropine sulfate (0.025 mg)*	1–2 tablets PO 4 times per day (30–60 min AC and HS); increase as needed up to 8 tables PO 4 times per day.
Codeine (15 mg–60 mg)*	30–60 mg PO 4 times per day (30–60 min AC and HS) and increase as needed.
Tincture of opium (0.3–1.0 mL)	6–20 drops PO 4 times per day (30–60 min AC and HS) and increase by 5–10 drops per dose up to 6 times per day as needed.
Histamine H-2 blockers	
Famotidine	20–40 mg PO or IV 2 times per day.
Ranitidine	150–300 mg PO 2 times per day or 300 mg PO once daily or 50 mg IV every 6–8 h.
Cimetidine	400 mg PO or IV 4 times per day.
Proton-pump inhibitors	
Omeprazole	40 mg PO 2 times per day.
Lansoprazole	30 mg PO every day to 2 times per day; 30 mg IV once daily for up to 7 days.
Protonix	40 mg IV or PO every day to 2 times per day.
Somatostatin analogue	
Octreotide	Start with 100 μg 3 times per day (subcutaneously or in PN); long-acting form available.

PO, by mouth; AC, before meals; HS, at bedtime; HCl, hydrochloric acid.
*Available as pill or liquid.

jejunum is rarely resected in SBS, many patients tolerate lactose in the diet so it is unnecessary to restrict these food choices. Foods containing lactose improve the palatability of the diet and are important sources of protein, calcium, and vitamin D.[37] Marteau et al[37] compared a lactose-free diet to a diet containing 20 g/day of lactose in 14 patients with SBS. There was no difference in lactose absorption, breath hydrogen, or subjective symptoms of flatulence, and diarrhea was similar regardless of which diet was consumed. These data confirmed the findings of an earlier study in 17 patients with SBS where it was also reported that lactose absorption was enhanced when provided in yogurt rather than milk.[38]

Protein

Many patients with SBS are malnourished and may benefit from increased levels of protein, generally comprising 20% of the calories of the diet. The best type of protein to supply also has not been clearly defined. McIntyre and colleagues[31] compared energy, nitrogen, and fat absorption in 7 patients with end-jejunostomies (remnant small intestine range of 60–150 cm) fed either a peptide-based formula or an isocaloric and isonitrogenous polymeric formula. There were no differences in energy, nitrogen, fat, carbohydrate, electrolyte, mineral, or fluid absorption. These data were confirmed in another small, uncontrolled study by Levy et al.[39] However, in a study of 6 patients with 90–150 cm of residual jejunum and end-jejunostomy, nitrogen absorption was improved with the use of a peptide-based diet.[40] Energy, carbohydrate, fat, electrolyte, mineral, and fluid absorption were unaffected. In each of these studies, the sample size was small, the study populations were heterogeneous, and the various peptide constituents and concentrations varied significantly. Due to the complex nature of dietary protein foodstuffs, they are generally well tolerated by patients with SBS. Use of whole-protein foods also improves the palatability of the diet. Protein of high-biologic value from eggs, chicken, turkey, fish, beef, and pork are encouraged. In some instances when fat needs to be restricted, the protein should be selected from leaner cuts of meat and prepared by a method that does not contribute to the overall fat content.

GLN has been shown to prevent mucosal atrophy and deterioration in gut permeability in patients receiving PN.[41] However, no benefit was observed in fluid or sodium absorption when GLN was added to ORS given to patients with SBS.[42] In a randomized, controlled, crossover study, the role of oral GLN and diet was evaluated in 8 patients with SBS.[43] There were no differences in small bowel morphology, transit time, D-xylose absorption, or stool output. However, this particular study may be limited by the differences in the diet during the active and placebo treatment. In the recent study by Byrne and colleagues,[29] patients receiving 30 g of oral GLN in addition to diet were able to reduce PN requirements. Maximum benefit was achieved with the combined therapy of diet, GLN, and growth hormone.

Fat

Fat is important in the diet as it supplies energy, essential fatty acids, and fat-soluble vitamins. When the colon is absent or out of circuit, fat absorption from the diet is relatively constant over a broad range.[27] Allowing a higher percentage of calories in the diet derived from fat for patients without a colon will improve the palatability of the diet and potentially increase the number of calories absorbed. However, in our clinical experience, excessive intakes of fat (>40% of total calories) are generally not well tolerated and will result in increased output. When the colon is in continuity, fat restriction of approximately 20%–30% of total calories will help to improve absorption and minimize output.[8,33] For both groups of patients, with and without a colon, emphasis should be placed on consuming fats that are rich in essential fatty acids in order to prevent essential fatty acid deficiency.[44] Medium-chain triglycerides (MCT) do not require digestion by pancreatic enzymes for their absorption and are often used as part of the therapeutic plan for SBS without clear evidence to support their use. In a randomized, controlled, crossover trial of 19 SBS patients (10 with colon, 9 without colon), patients received long-chain triglycerides (LCT) and MCT plus LCT.[45] The diet enriched with MCT resulted in improved energy and fat absorption in the patients with a colon. However those patients without a colon only experienced a slight increase in fat absorption but no improvement in overall energy absorption due to a decrease in carbohydrate and protein absorption. Therefore, supplementation with MCT may be of some benefit in providing additional calories to those SBS patients with a colon. However, this does not supply essential fatty acids.

Fiber

Fiber has been classified in various ways but most often is referred to as soluble and insoluble. Insoluble fiber (eg, wheat bran) causes bulking of the stool and decreases transit time through the gut. Soluble fiber (eg, pectin, guar gum) slows gastric emptying and overall transit time. Patients are encouraged to include fiber from food sources such as oatmeal, oat bran, barley, and legumes as tolerated. When output is high, fiber supplements that increase viscosity are sometimes used to gelatinize the stool or ostomy effluent. When the colon is in circuit, undigested fermentable fiber is metabolized into SCFAs, primarily butyrate, propionate, and acetate. Propionate and acetate are thought to be metabolized in colonic epithelial cells or peripheral tissue. Butyrate

may regulate colon cell proliferation and serve as an energy source for colonocytes.[46] This can be a substantial source of calories for the patient with SBS. The patient with an intact colon may absorb up to 525–1170 kcal daily from the metabolism of dietary fiber.[23] However, colonic bacteria also metabolize fiber into hydrogen and methane, which results in flatulence in some patients. In our clinical experience, the tolerance of supplemental viscous fibers is variable in these patients and should be individualized.

Fluid

Oral fluid intake should exceed stool or stoma output in order to prevent dehydration. Patients with small bowel enterostomies or a limited length of colon are at an increased risk of dehydration because they secrete more sodium and fluid than they consume by mouth.[47] These patients may require ORS, which take advantage of active cotransport of sodium and glucose molecules at the intestinal brush border to maintain hydration.[48–51] Cotransport across the luminal membrane is facilitated by the protein sodium glucose cotransporter 1 (SGLT1). Once in the enterocyte, the transport of glucose into the blood is facilitated by glucose transporter type 2 (GLUT2) in the basolateral membrane. The Na+ K+ ATPase provides the gradient that drives the process. This mechanism remains intact, even in patients with severe diarrhea.[52] For optimal absorption, the composition of the rehydration solution is critical. The amount of fluid absorbed depends on 3 factors: the concentration of sodium, the concentration of glucose, and the osmolality of the luminal fluid. For individuals with a normal amount of bowel, maximal water uptake occurs with a sodium concentration from 40 to 90 mmol/L, a glucose concentration from 110 to 140 mmol/L (2.0–2.5 g/100 mL) and an osmolality of about 290 mOsm/L, the osmolality of body fluids. In patients with SBS, the optimal sodium concentration is 90–120 mmol/L.[53–55] When the glucose concentration is increased beyond 200 mOsm/L, the osmolality of the solution is increased, which may result in a net loss of water. Patients with at least one-half of the colon in circuit often have adequate sodium absorption, and ORSs may not be necessary.

There are numerous commercially available ORS (Table 3).[56] However, they vary considerably in terms of electrolyte and glucose composition and osmolality. Both hypo- and hyperosmolar solutions should be avoided. Solutions with lower sodium concentration can lead to increased sodium losses. Therefore patients with SBS should be cautioned against consumption of large amounts of plain water. Consumption of high-glucose-containing fluids without sodium may also cause an efflux of fluid and sodium across a gradient into the lumen of the bowel, thus contributing to dehydration and electrolyte abnormalities.[54,57]

Table 3 Composition of selected oral rehydration solutions

Product	Sodium mEq/L	Potassium mEq/L	Chloride mEq/L	Citrate mEq/L	Osmolarity mOsm/L	Glucose g/L
Ceralyte 50 (Cumberland Pharmaceuticals, Nashville, TN)	50	20	98	30	<220	40
Ceralyte 70 (Cumberland Pharmaceuticals)	70	20	98	30	235	40
Ceralyte 90 (Cumberland Pharmaceuticals)	90	20	98	30	260	40
Equalyte (Ross Products Division, Abbott Laboratories, Columbus, OH)	78	22	68	30	305	25
Pedialyte (Ross Products Division, Abbott Laboratories)	45	20	35	30	300	20
Rehydralyte (Ross Products Division, Abbott Laboratories)	75	20	65	30	300	25
World Health Organization (WHO, Geneva Switzerland)	90	20	80	30	200	20
Washington University (St. Louis, MO)	105	0	100	10	250	20

Reprinted from reference 56, p 59 by courtesy of Taylor and Francis Group, LLC.

Oxalates

One of the potential long-term complications of fat malabsorption is the development of oxalate nephropathy that occurs in approximately 25% of patients with <200 cm of small bowel who have a colon in continuity.[23] Normally, oxalate in the diet is bound to calcium and very little oxalate ion is free to be absorbed in the colon. Patients with SBS who have a retained colon are at increased risk of oxalate nephropathy because unabsorbed fatty acids bind to calcium in the lumen of the bowel, leaving oxalate ion free to be absorbed. Once absorbed, oxalate is excreted by the kidney, causing oxalate stones. A low-oxalate diet reduces oxalate absorption and thus urinary excretion. Additional oral calcium can also be provided to bind the oxalate along with a low-fat diet to prevent absorption.

Vitamin and Mineral Supplementation

Micronutrient supplementation will be necessary particularly as patients are weaned from PN. Vitamin and mineral deficiencies are common in these patients, and they often present with clinical signs of nutrient deficiencies.[58,59] Many supplements will be incompletely absorbed in patients with SBS, and doses exceeding the dietary reference intakes (DRI) are often required to maintain normal serum levels. Although the patients are at risk of multiple vitamin and mineral deficiencies, in our experience, supplementation of certain nutrients is almost uniformly required. Patients with significant resections of the ileum will require routine vitamin B_{12} injections.[9] Patients with SBS resulting from resections for Crohn's disease are often taking corticosteroids for prolonged periods of time. This, combined with chronic malabsorption, often leads to osteopenia and osteomalacia. Thus, supplementation with calcium and vitamin D will be important. With increased stoma or stool losses, there are increased losses of magnesium. Magnesium is a divalent cation that is poorly absorbed in the intestine, and certain forms of magnesium act as a cathartic, thus making the situation worse. Supplementation with magnesium lactate or gluconate is preferred because they do not increase output as much as other forms such as magnesium oxide. In addition, magnesium lactate is calcium sparing and thus may be of benefit in these patients. Zinc supplementation is also important.[60] Deficiency of zinc has been associated with diarrhea. Increased diarrhea results in more zinc losses, so a vicious cycle is created.[61] If the length of bowel is particularly short and transit time rapid, the patient may benefit from vitamins and minerals in chewable or liquid form.

Trophic Factors

Although a reduction in PN can be achieved with the use of dietary modification, fiber, ORS, and standard medications, some patients may benefit from the use of growth factors. Interest has centered around the use of several growth factors, including growth hormone (rGH), glucagon-like peptide 2 (GLP-2), keratinocyte growth factor (KGF), epidermal growth factor (EGF), and insulin like growth factor 1 (IGF-1). Each of these is in various stages of research and development, but rGH and GLP-2 are the only growth factors tested in humans with SBS. Both of these have shown efficacy in improving nutrient absorption.[29,62–68] In December 2003, the US Food and Drug Administration approved the use of rGH for the treatment of SBS according to the completion of a phase III randomized, double-blind, placebo-controlled clinical trial[29] and expert testimony. More detailed reviews of this subject have been published elsewhere[69,70] and in this issue.[71]

Education, Monitoring and Weaning

A strong educational component is imperative in order to optimize clinical outcomes. Patients must be taught not only what to eat but how to eat. In translating the nutrition prescription into diet, the therapeutic plan should be tailored to fit the lifestyle, preferences, and needs of the individual patient. This will help to ensure compliance and positive results. Although all attempts are made to base the diet and overall therapeutic plan on the GI anatomy of the patient, it should be noted that there is a great deal of inter- and intrapatient variability. Therefore, individual goals for nutrient and fluid intake should be set and adjusted as the patient's needs change.

The importance of monitoring these patients while trying to transition them to oral nutrition cannot be over emphasized. As the bowel adapts and begins to absorb more, adjustments will have to be made in the PN solution, both in terms of volume and composition. Monitoring is important before the weaning process is begun in order to determine the best time to begin.

There is a lack of published guidelines regarding the optimal methods of weaning patients from PN. Before weaning from PN to an enteral diet, it is necessary to ensure that the hydration and nutrition needs of the patient can be met. This is an evolving process and continues throughout the weaning procedures. It is also important to establish realistic goals with the patient. The patient needs to be aware that weaning may not result in complete autonomy from PN but a reduction in the frequency. Weaning from PN can be accomplished by reducing the total volume or by slowly reducing the frequency of the infusion. Most patients would prefer to have a night of not receiving PN. Thus, during this process, PN can be eliminated 1or 2 nights per week and gradually advanced until they are no longer receiving the infusion. It is best to space out the infusions and avoid giving the patients back-to-back nights off. As the PN is reduced, electrolytes and micronutrients may have to be replaced enterally. Vitamins

and minerals should be supplemented on non-PN days. It will be necessary to monitor micronutrient and electrolyte status once patients are completely weaned from receiving PN.

Surgical Reconstruction as a Component of Intestinal Rehabilitation

There are some patients who will fail attempts at intestinal rehabilitation with diet, and adjunctive medication and surgical options for preventing dehydration and malnutrition will have to be considered. During the initial surgical resection, it is important to preserve as much of the existing intestine as possible using surgical techniques such as stricturoplasty for strictures, serosal patches for strictures and perforations, and intestinal tapering and lengthening procedures for dilated segments of bowel.[72,73] Surgical intestinal rehabilitation or autologous GI reconstruction is used to restore intestinal continuity by reanastomosing isolated loops of bowel to provide more absorptive surface, lengthen, taper, or relieve obstructions. In some instances, it may be necessary to slow transit by using a reversed segment. Only a small number of patients will be candidates for these reconstructive procedures, but with appropriate patient selection, it may provide autonomy from PN.

When Intestinal Rehabilitation Cannot Be Achieved

Patients who fail intestinal rehabilitation efforts can also be supported with long-term PN. This has been considered a standard life-saving therapy for more than 3 decades. However, considering the cost, risks, and long-term outcomes of HPN,[74] small bowel transplantation with or without other viscera should be considered. Between April 1985 and May 2003, a total of 923 patients received 989 intestinal transplants at 61 centers worldwide.[75] Of these, 76% (n = 747) were transplanted in the United States, with 33% (n = 247) being performed at the University of Pittsburgh Medical Center. As of May 31, 2003, a total of 484 intestinal recipients were alive worldwide, with an overall survival rate of 52%.[75] With the improvements in surgical technique and antirejection therapy, survival has been improving over the last decade. The 1-year patient and graft survival rates for those who were transplanted after February of 1998 were 77% and 65% for isolated intestine, 60% and 59% for combined liver-small bowel, and 66% and 61% for multivisceral graphs, respectively. The University of Pittsburgh's experience over the last decade has been published as a single-center experience.[76] Between May 1990 and February 2000, a total of 165 transplants were given to 155 consecutive recipients. The survival rate for the total population was 75% at 1 year and 54% at 5 years, with achievement of full nutrition autonomy in 90% of the survivors. With the recent implementation of pretreatment/induction therapy, particularly with rATG or Campath 1H,[77] 1- and 3-year patient survival was 91% and 81%, with a graft survival rate of 85% and 70%, respectively (unpublished data). The 1- and 3-year survival for all HPN patients is 87%–96% and 70%–90%, respectively.[3,78] For those patients with GI disorders, the survival rates for HPN ranged from 65%–80%.[79]

Conclusion

The management of patients with SBS is complex and requires a comprehensive, multidisciplinary approach and attention to detail. Although the data on the nutrition management of the patient with SBS are limited, it is apparent from clinical practice that careful and meticulous nutrition intervention can facilitate weaning from PN. The use of specific nutrients or nonnutritive components of foods may benefit some patients. Long term, the use of appropriate oral diets, coupled with adequate patient education and monitoring, will improve the chances for nutrition autonomy. When nutrition autonomy cannot be achieved through efforts in a rehabilitation program and the patient fails HPN, small bowel transplantation should be considered. The ultimate goal is to improve the nutrition status of these patients through the safest, most efficacious method that will improve the quality of their lives.

References

1. Nightingale J, Spiller R. Normal intestinal anatomy and physiology. In: Nightingale J, ed. *Intestinal Failure.* London: Greenwich Medical Media Limited; 2001:15–36.
2. Buchman AL, Scolapio J, Fryer J. American Gastroenterological Association Medical Position Statement: short bowel syndrome and intestinal transplantation. *Gastroenterology.* 2003;124:1105–1110.
3. Howard L, Ament M, Fleming CR, Shike M, Steiger E. Current use and clinical outcome of home parenteral and enteral nutrition therapies in the United States. *Gastroenterology.* 1995;109:355–365.
4. Howard L, Ashley C. Management of complications in patients receiving home parenteral nutrition. *Gastroenterology.* 2003;124:1651–1661.
5. O'Keefe SJ, Burnes JU, Thompson RL. Recurrent sepsis in home parenteral nutrition patients: an analysis of risk factors. *JPEN J Parenter Enteral Nutr.* 1994;18:256–263.
6. Jeppesen PB, Langholz E, Mortensen PB. Quality of life in patients receiving home parenteral nutrition. *Gut.* 1999;44:844–852.
7. Nightingale JMD, Lennard-Jones JE. The short bowel syndrome: what's new and old? *Dig Dis.* 1993;11:12–31.
8. Lennard-Jones JE. Review article: practical management of the short bowel. *Aliment Pharmacol Ther.* 1994;8:563–577.
9. Okuda K. Discovery of vitamin B12 in the liver and its absorption factor in the stomach: a historical review. *J Gastroenterol Hepatol.* 1999;14:301–308.
10. Hofmann AF, Poley JR. Role of bile acid malabsorption in the pathogenesis of diarrhea and steatorrhea in patients with ileal resection, I: response to cholestyramine or replacement of dietary long-chain triglycerides by medium-chain triglycerides. *Gastroenterology.* 1972;62:918–934.
11. Ricotta J, Zuidema GD, Gadacz TR, Sadri D. Construction of an ileocecal valve and its role in massive resection of the small intestine. *Surg Gynecol Obstet.* 1981;152:310–314.

12. Fich A, Steadman CJ, Phillips SF, et al. Ileocolonic transit does not change after right hemicolectomy. *Gastroenterology.* 1992; 103:794–799.
13. Singleton AO, Redmond DC, McMurray JE. Ileocecal resection and small bowel transit and absorption. *Ann Surg.* 1964;159:690–694.
14. Weser E. Nutritional aspects of malabsorption: short gut adaptation. *Clin Gastroenterol.* 1983;12:443–461.
15. Dudrick SJ, Latifi R, Fosnocht DE. Management of the short bowel syndrome. *Surg Clin North Am.* 1991;71:625–643.
16. Rombeau JL, Rolandelli RH. Enteral and parenteral nutrition in patients with enteric fistulas and short bowel syndrome. *Surg Clin North Am.* 1987;67:551–571.
17. Solhaug JH, Tvete S. Adaptive changes in the small intestine following bypass operation for obesity. *Scand J Gastroenterol.* 1978;13:401–408.
18. Doldi SB. Intestinal adaptation following jejunal-ileal bypass. *Clin Nutr.* 1991;10:138–145.
19. Dowling RH, Booth DB. Functional compensation after small bowel resection in man. *Lancet.* 1966;2:146–147.
20. Weinstein LD, Shoemaker Herst T, Wright HK. Enhanced intestinal absorption after small bowel resection in man. *Arch Surg.* 1968;99:560–561.
21. Ziegler TR, Fernandez-Estivariz C, Gu LH, et al. Distribution of the H+/peptide transporter PepT1 in human intestine: up-regulated expression in the colonic mucosa of patients with short bowel syndrome. *Am J Clin Nutr.* 2002;75:922–930.
22. Messing B, Crenn P, Beau P, Boutron-Ruault MC, Rambbaud JC, Matuchausky C. Long-term survival and parenteral nutrition dependence in adult patients with short bowel syndrome. *Gastroenterology.* 1999;117:1043–1050.
23. Nightingale JM, Lennard-Jones JE, Gertner DJ, Wood SR, Bartram CI. Colonic preservation reduces need for parenteral therapy, increases incidence of renal stones, but does not change high prevalence of gallstones in patients with a short bowel. *Gut.* 1992;33:1493–1497.
24. Kurkchubasche AG, Smith SD. Adaptation in short bowel syndrome: reassessing old limits. *J Pediatr Surg.* 1993;28:1069–1071.
25. Feldman E J, Dowling RH, McNaughton J, Peters TJ. Effects of oral versus intravenous nutrition on intestinal adaptation after small bowel resection in the dog. *Gastroenterology.* 1976;70:712–919.
26. Ovesen L, Chu R, Howard L. The influence of dietary fat on jejunostomy output in patients with severe short bowel syndrome. *Am J Clin Nutr.* 1983;38:270–277.
27. Woolf GM, Miller C, Kurian R, Jeejeebhoy KN. Diet for patients with short bowel: high fat or high carbohydrate? *Gastroenterology.* 1983;84:823–828.
28. Nordgaard I, Hensen BS, Mortensen PB. Colon as a digestive organ in patients with short bowel. *Lancet.* 1994;343:373–376.
29. Byrne TA, Wilmore DW, Iyer K, et al. Growth hormone and an optimal diet with or without glutamine reduces parenteral nutrition in patients with short bowel syndrome. *Ann Surg*. 2005. In press.
30. Scolapio JS. Short bowel syndrome. *JPEN J Parenter Enteral Nutr.* 2002;26(5 suppl):S11–S16.
31. McIntyre PB, Fitchew M, Lennard-Jones JE. Patients with a high jejunostomy do not need a special diet. *Gastroenterology.* 1986;91: 25–33.
32. Byrne TA, Cox S, Karimbakas MN, Weseman RA. The role of diet and specific nutrients. In: Matarese LE, Steiger E, Seidner DL, eds. *Intestinal Failure and Rehabilitation: A Clinical Guide*. Boca Raton, FL: CRC Press; 2005:129–147.
33. Byrne TA, Veglia L, Camelio M, et al. Beyond the prescription: optimizing the diet of patients with short bowel syndrome. *Nutr Clin Pract.* 2000;15:306–311.
34. Rodigues, CA, Lennard-Jones JE, Thompson DG. Energy absorption as a measure of intestinal failure in the short bowel. *Gut.* 1989;30:176–183.
35. Messing B, Pigot F, Rongier M. Intestinal absorption of free oral hyperalimentation in the very short bowel syndrome. *Gastroenterology.* 1991;100:1502–1508.
36. Seidner DL, Matarese LE. Etiology, pathophysiology and management: selected topics in gastrotherapy. Available at http://www.clevelandclinicmeded.com/selected_topics/shortbowel/summary/article.htm. Accessed February 23, 2005.
37. Marteau P, Messing B, Arrigoni E, et al. Do short bowel patients need a lactose-free diet? *Nutrition.* 1997;13:13–16.
38. Arrigoni E, Marteau P, Briet F, Pochart P, Rambaud JC, Messing B. Tolerance and absorption of lactose from milk and yogurt during short-bowel syndrome in humans. *Am J Clin Nutr.* 1994; 60:926–929.
39. Levy E, Frileux P, Sandrucci S, et al. Continuous enteral nutrition during the early adaptive stage of the short bowel syndrome. *Br J Surg.* 1988;75:549–553.
40. Cosnes J, Evard D, Beaugerie L, Gendre JP, Le Quintrec Y. Improvement in protein absorption with a small peptide-base diet in patients with high jejunostomy. *Nutrition.* 1992;8:406–411.
41. van der Hulst RR, van Kreel BK, von Meyenfeldt MF, et al. Glutamine and the preservation of gut integrity. *Lancet.* 1993; 341:1363–1365.
42. Beaugerie L, Carbonnel F, Hecketsweiler B, Dechelotte P, Gendre JP, Cosnes J. Effects of an isotonic oral rehydration solution, enriched with glutamine, or fluid and sodium absorption in patients with a short bowel. *Aliment Pharmacol Ther.* 1997;11: 741–747.
43. Scolapio JS, McGreevy K, Tennyson GS, Burnett OL. Effect of glutamine in short-bowel syndrome. *Clin Nutr.* 2001;20:319–323.
44. Jeppesen PB, Hoy CE, Mortensen PB. Deficiencies of essential fatty acids, vitamin A and E and changes in plasma lipoproteins in patients with reduced fat absorption or intestinal failure. *Eur J Clin Nutr.* 2000;54:632–642.
45. Jeppesen PB, Mortensen PB. The influence of a preserved colon on the absorption of medium chain fat in patients with small bowel resection. *Gut.* 1998;43:478–483.
46. Bond JH, Currier BE, Buchwald H, Levitt MD. Colonic conservation of malabsorbed carbohydrate. *Gastroenterology.* 1980;78: 444–447.
47. Nightingale JMD, Lennard-Jones JE, Walker ER, Farthing MJG. Jejunal efflux in short bowel syndrome. *Lancet.* 1990;336:765–768.
48. Curran PF. Na, Cl and water transport by rat ileum in vitro. *J Gen Physiol.* 1960;43:1137–1148.
49. Camilleri M, Prather CM, Evans MA, Andresen-Reid ML. Balance studies and polymeric glucose solution to optimize therapy after massive intestinal resection. *Mayo Clin Proc.* 1992;67:755–760.
50. Lennard-Jones JE. Oral rehydration solutions in short bowel syndrome. *Clin Thera.* 1990;12(suppl A):129–137.
51. Fortran JS. Stimulation of active and passive sodium absorption by sugars in the human jejunum. *J Clin Invest.* 1975;55:728–737.
52. Pierce NF, Banwell JG, Rupak DM, et al. Effect of intragastric glucose-electrolyte infusion upon water and electrolyte balance in Asiatic cholera. *Gastroenterology.* 1968;55:333–343.
53. Rodrigues CA, Lennard-Jones JE, Thompson DG, Farthing MJG. What is the ideal sodium concentration of oral rehydration solutions (ORS) for short bowel patients [abstract]? *Clin Sci.* 1988;74(suppl 18):69.
54. Spiller RC, Jones BMJ, Silk DBA. Jejunal water and electrolyte absorption from two proprietary enteral feeds in man: importance of sodium content. *Gut.* 1987;28:681–687.
55. Sladen GE, Dawson AM. Inter-relationships between the absorption of glucose, sodium and water by the normal human jejunum. *Clin Sci.* 1969;36:119–132.
56. Ukleja A, Scolapio JS. Abnormalities in fluid and electrolyte absorption in intestinal failure. In: Matarese LE, Steiger E, Seidner DL, eds. *Intestinal Failure and Rehabilitation: A Clinical Guide.* Boca Raton, FL: CRC Press; 2005:49–65.
57. Nightingale JMD, Lennard-Jones JE, Walker ER, Farthing MJG. Oral salt supplements to compensate for jejunostomy losses: comparison of sodium chloride capsules, glucose electrolyte solution, and glucose polymer electrolyte solution. *Gut.* 1992;33:759–761.
58. Cox S, Karimbakas M, Byrne T. The incidence of nutrient abnormalities in patients dependent upon long-term PN [abstract]. *Nutr Clin Pract.* 2002;17:N40.

59. Burnes JU, O'Keefe SJ, Fleming CR, Devine RM, Berkner S, Herrick L. Home parenteral nutrition: a 3-year analysis of clinical and laboratory monitoring. *JPEN J Parenter Enteral Nutr.* 1992; 16:327–332.
60. Matarese LE, Steiger E, Seidner DL. Review of a potential role for zinc supplementation in oral rehydration solutions. *Nutr Clin Pract.* 2003;18:240–246.
61. Semrad CE. Zinc and intestinal function. *Curr Gastroenterol Rep.* 1999;1:398–403.
62. Byrne TA, Morrissey TB, Nattakom TV, Ziegler TR, Wilmore DW. Growth hormone, glutamine, and a modified diet enhance nutrient absorption in patients with severe short bowel syndrome. *JPEN J Parenter Enteral Nutr.* 1995;19:296–302.
63. Byrne TA, Persinger RL, Young LS, Ziegler TR, Wilmore DW. A new treatment for patients with short-bowel syndrome: growth hormone, glutamine, and a modified diet. *Ann Surg.* 1995;222: 243–255.
64. Byrne TA, Cox S, Karimbakas M, et al. Bowel rehabilitation: an alternative to long-term parenteral nutrition and intestinal transplantation for some patients with short bowel syndrome. *Transplant Proc.* 2002;34:887–890.
65. Wu GH, Wu ZH, Wu ZG. Effects of bowel rehabilitation and combined trophic therapy on intestinal adaptation in short bowel patients. *World J Gastroenterol.* 2003;9:2601–2604.
66. Seguy D, Kouroche V, Nathalie K, Souberbielle JC, Messing B. Low-dose growth hormone in adult home parenteral nutrition-dependent short bowel syndrome patients: a positive study. *Gastroenterology.* 2003;124:293–302.
67. Jeppesen PB, Hartmann B, Thulesen J, et al. Glucagon-like peptide 2 improves nutrient absorption and nutritional status in short-bowel patients with no colon. *Gastroenterology.* 2001;120: 806–815.
68. Jeppesen PB, Blosch CM, Lopansri JB, et al. ALX-0600, a dipeptidyl peptidase-IV resistant glucagon like peptide-2 (GLP-2) analog, improves intestinal function in short bowel syndrome (SBS) patients with a jejunostomy [abstract]. *Gastroenterology.* 2002; 122(suppl):A1191.
69. Matarese LE, Seidner DL, Steiger E. Growth hormone, glutamine, and modified diet for intestinal adaptation. *J Am Diet Assoc.* 2004;104:1265–1272.
70. Matarese LE, Abu-Elmagd K. Somatropin for the treatment of short bowel syndrome in adults. *Expert Opin Pharcother.* 2005;6: 1741–1750.
71. Parekh NR, Steiger E. Criteria for the use of recombinant human growth hormone in short bowel syndrome. *Nutr Clin Pract.* 2005;20:503–508.
72. Thompson JS. Strategies for preserving intestinal length in the short bowel syndrome. *Dis Col Rectum.* 1987;30:208–213.
73. Devine RM, Kelly KA. Surgical therapy of the short bowel syndrome. *Gastroenterol Clin North Am.* 1989;18:603–618.
74. Van Gossum A, Vahedi K, Abdel-Malik, et al. Clinical, social and rehabilitation status of long-term home parenteral nutrition patients: results of a European multicentre survey. *Clin Nutr.* 2001;20:205–210.
75. Grant D, Abu-Elmagd K, Reyes J, et al. 2003 Report of the intestine transplant registry: a new era has dawned. *Ann Surg.* 2005;241:607–613.
76. Abu-Elmagd K, Reyes J, Bond G, et al. Clinical intestinal transplantation: a decade of experience at a single center. *Ann Surg.* 2001;234:404–417.
77. Starzl TE, Murase N, Abu-Elmagd K, et al. Tolerogenic immunosuppression for organ transplantation. *Lancet.* 2003;361:1502–1510.
78. Messing B, Lemann M, Landais P, et al. Prognosis of patients with nonmalignant chronic intestinal failure receiving long-term home parenteral nutrition. *Gastroenterology.* 1995;108:1005–1010.
79. Howard L, Heaphey L, Fleming CR, Lininger L, Steiger E. Four years of North American registry home parenteral nutrition outcome data and their implications for patient management. *JPEN J Parenter Enteral Nutr.* 1991;15:384–393.