Short Bowel Syndrome

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Opinion statement

Treatment of short bowel syndrome (SBS) is often a difficult endeavor due to the high variability among patients with SBS in regard to remaining anatomical structure and functional capacity. Research efforts to substantiate the use of existing therapies in the treatment of SBS are ongoing, with newer developments yet to be fully explored. Current therapy for SBS begins with the implementation of a modified diet based on the presence or absence of the colon. Patients with difficulty ingesting enough nutrients and fluids for weight maintenance and fluid balance may benefit from nocturnal enteral nutrition and hydration. Those with inadequate absorptive capacity despite maximization of oral and enteral intake will need parenteral nutrition (PN) or hydration. Medications, including antisecretory agents, antidiarrheals, pancreatic enzymes, bile acid sequestrants, and antibiotics, often are useful in abating symptoms commonly associated with SBS. Growth factors, including recombinant human growth hormone and glucagon-like peptide 2, may be trialed to stimulate intestinal adaptation and enhance absorption in PN-dependent SBS patients. The gradual refinement of surgical procedures for SBS, including small bowel transplantation, has led to improved outcomes, and early referral of SBS patients to centers of excellence will optimize care.

Introduction

Short bowel syndrome (SBS) is traditionally defined as less than 200 cm of remaining viable jejunum and ileum following surgical resection for disease, trauma, infarction, or congenital defect. Surgical therapy for weight loss, including gastric or intestinal bypass surgery, and its complications also may lead to SBS. Depending on the remaining anatomical configuration and the duration following resection, SBS can result in extensive nutrient and fluid losses. Gastric acid hypersecretion, inactivation of endogenous pancreatic enzymes, bile acid wasting, rapid intestinal transit, reduced absorptive surface area, and small bowel bacterial overgrowth are common sequelae of SBS contributing to the degree of malabsorption suffered. In addition, the risk for gallstone formation, renal calculi, liver dysfunction, and metabolic bone disease increases over time in patients with severe SBS [1]. Therapy is highly individualized, outcomes are monitored closely, and interventions are modified routinely based on patient progress.

The first step in forming a treatment plan for SBS is an assessment of the remaining bowel anatomy. A jejunal resection with intact terminal ileum and colon generally is well tolerated due to the ability of the lower bowel to compensate by increasing absorptive function. This adaptive response begins immediately following resection and proceeds for up to 2 years, with the main response occurring within a few months of resection [2]. A terminal ileal resection of less than 100 cm often leads to a cholerrheic diarrhea, whereas a more extensive ileal resection will provoke chronic steatorrhea and a watery diarrhea. Preservation of the colon in treatment of SBS is important for bacterial fermentation of undigested carbohydrates into short-chain fatty acids, which can enhance fluid and electrolyte absorption and serve as an additional source of energy. In a study of home parenteral nutrition (HPN) patients with SBS [3], researchers found that those with remaining small bowel of less than 100 cm (n = 24, mean 50 cm) required 50% less energy via PN if 50% or more

of their colon was functional. Absence of the colon in those with less than 100 cm of jejunum–ileum remaining will likely result in long-term dependence on parenteral nutrient and/or fluid and electrolyte supplementation [4].

After an assessment of bowel anatomy, a thorough evaluation of the patient's nutritional status, dietary intake, and average daily output should be conducted. Nutrient balance studies are very difficult to perform accurately in the outpatient setting and most often are reserved for use in clinical research. A usual intake and output recall, including enteral and parenteral intake, urine and gastrointestinal (GI) losses, weight fluctuations, and activity level, generally is sufficient. Laboratory testing should consist of a full electrolyte and liver function test panel with serum magnesium, trace minerals, fat-soluble vitamins, ionized calcium, parathyroid hormone, and vitamin B_{12}. Patients with SBS commonly become deficient in magnesium, calcium, zinc, and certain vitamins, depending upon the area of bowel resection. A careful examination for clinical signs of deficiency, such as dermatitis, dyspnea, alopecia, peripheral edema, and paresthesias, should be performed. Once the SBS patient has been thoroughly evaluated, an informed decision may be made as to which mode of therapy to undertake.

Management of SBS is directed toward minimizing GI symptoms and maximizing absorptive capacity to maintain fluid, electrolyte, and nutrient balance. Treatment options are divided into dietary, medical, and surgical interventions, with many patients requiring a combination to achieve an acceptable degree of GI relief and nutritional homeostasis. All patients with SBS generally will benefit from a diet divided into several small meals per day and limited in simple sugars in order to minimize the osmolar load to the GI tract. This includes the limitation or dilution of fruit juices, sugary sports drinks, and regular sodas. For SBS patients with colon, a diet high in complex carbohydrates (50% to 60% of total calories) and low in fat (20% to 30% of total calories) with isotonic or hypotonic fluids sipped between meals is recommended [5]. In SBS patients without colon, a moderate-carbohydrate (40% to 50% of total calories), moderate-fat (30% to 40% of total calories), calorically dense diet is most optimal [5].

Sodium and fluid transport across the upper intestinal membrane occurs through a sodium–glucose cotransport system, whereby active sodium absorption and subsequent water absorption are achieved through solvent drag. Thus, patients with small bowel enterostomies or very limited colon should be instructed to sip isotonic glucose–electrolyte solutions (oral rehydration solutions [ORS]) with approximately 90 mEq sodium/L (1 teaspoon salt/L) and 20 g glucose/L. Hypotonic, sodium-free fluids such as water and tea should be avoided, as these may provoke additional loss of fluids and electrolytes. Patients with less than 65 cm jejunum without colon often have fluid losses in excess of 3 L/d. In these cases, oral intake should be limited to several extremely small meals per day, and fluid intake may need to be restricted to no more than 1.5 L of ORS sipped daily. This type of restriction is imposed in order to reduce losses to the point at which intravenous replacement can occur safely in the home setting.

Newer nutrient-based treatments being researched for use in treatment of SBS include oleic acid to delay intestinal transit and parenteral fish oil emulsions to treat PN-associated liver disease (PNALD). Oleic acid, 3.2 mL ingested with a small meal, increased small bowel transit time from an average of 29.3 minutes to an average of 83.3 minutes in 45 patients with chronic diarrhea [6]. Olive oil is a readily available source of oleic acid; however, studies have not been done on its use in the treatment of SBS. Experimental use of a parenteral fish oil-based lipid emulsion in two infants with SBS and worsening PNALD led to a complete resolution of cholestasis in both infants within 8 weeks of therapy [7]. Larger trials are needed to confirm these findings and promote approval of the use of fish oil-based lipid emulsions in the United States.

Medical therapy for SBS often is initiated empirically and adjusted based on GI symptomology. Gastric acid hypersecretion occurs in most patients with SBS for up to 6 months following surgery, warranting treatment with histamine-2 blockers (H2Bs) or proton-pump inhibitors (PPIs) [8]. Antidiarrheal medications should be taken at least 30 minutes before meals in order to slow gastric and intestinal transit in SBS patients free of ileus or obstruction. A trial of oral pancreatic enzyme preparations also may be attempted to enhance digestion by allowing food to mix with enzymes in the stomach prior to entering the shortened bowel. Use of octreotide or clonidine to inhibit GI secretions and delay small bowel transit is best reserved for patients with large-volume secretory diarrhea refractory to standard antidiarrheal and antisecretory therapy [9,10].

Patients with an ileal resection of less than 100 cm attached to some portion of colon may benefit from bile acid-binding resins such as cholestyramine to reduce the irritation of bile acid contact with the colonic mucosa. For patients with an ileal resection of greater than 100 cm, researchers in Europe have developed an enteric-coated semisynthetic bile salt (cholylsarcosine) potentially useful in bile salt replacement therapy [11]. In a small pilot study involving three SBS patients, 7 days of oral cholylsarcosine with meals led to an improved level of fat absorption in all three patients [11]. Cholylsarcosine has not yet been approved by the US Food and Drug Administration (FDA) and currently is reserved for experimental use in the United States.

Small intestinal bacterial overgrowth (SIBO) is commonly suspected in SBS patients with increased gas; bloating; distention; odorous, loose stools; and abdominal discomfort. Treatment involves the empiric trial of broad-spectrum oral antibiotics for a period of 7 to 10

days. Success of treatment is based on an improvement in symptoms, including a reduction in gas and stool output and possible weight gain within 1 to 2 weeks of therapy [12]. The use of probiotics, or live beneficial microbial supplements, to restore beneficial bacterial flora after treatment with antibiotics has generated recent interest. Gaon et al. [13] compared the use of probiotics (*Lactobacillus casei* and *Lactobacillus acidophilus*) with placebo in a randomized, blinded trial of 22 patients with SIBO due to surgical blind loops, strictures, or partial small bowel obstruction. Those receiving probiotics experienced a significant reduction in the mean daily number of stools within 2 to 3 weeks of treatment and sustained this reduction up to a week after stopping the probiotics [13]. Further controlled trials are needed to confirm the benefits of probiotics in patients with SBS.

Efforts to develop new treatment modalities for SBS have centered on the use of humoral factors thought to affect intestinal growth and promote return of absorptive function postresection [14]. At the end of 2003, the FDA approved the use of recombinant human growth hormone (GH) as an adjunctive pharmacologic therapy for the treatment of SBS-induced malabsorption and malnutrition [15••]. Debate still exists over whether the reduction in PN observed within the GH literature is a result of the GH or of intensive diet modification alone [16]. A recent phase II trial on the use of a glucagon-like peptide 2 (GLP-2) analogue in SBS patients documented safety, tolerance, and increased intestinal wet weight absorption after 21 days of treatment [17••]. However, these positive results did not persist when therapy was discontinued. A phase III, multi-institutional, controlled trial is in progress to assess the optimal dosage and administration and to evaluate long-term clinical benefits of GLP-2 in the treatment of SBS.

Surgical options to improve intestinal function include operations to restore intestinal continuity, relieve obstruction, lengthen remaining intestine, or taper dilated bowel, or small bowel transplantation. Bowel lengthening, first proposed by Bianchi in 1980, has been used most often in the pediatric SBS population to improve motility, prolong intestinal transit, and potentially wean patients off of PN [18]. A newer technique of bowel lengthening known as serial transverse enteroplasty (STEP) has been described to treat severe bowel dilation and bacterial overgrowth in SBS with minimal complications and encouraging outcomes [19].

Outcomes of small bowel transplantation are gradually improving with better understanding of transplantation technique and immune modulation. The 1-year survival rate of patients undergoing small bowel transplantation is now 77%, with 5-year survival approaching 50% [20]. Transplantation of ileal stem cells into a jejunal segment of rats was able to reverse the bile acid malabsorption commonly seen post-ileal resection [21]. With further research, intestinal stem cell gene therapy may prove to be an important new therapy for SBS and its varying sequelae.

Intestinal rehabilitation programs have been established worldwide to provide the multidisciplinary effort necessary to optimize the care of patients with SBS. The main goal of these programs is to safely reduce the need for long-term PN through dietary and medical therapy with referral for surgical reconstruction or bowel transplantation before life-threatening complications of SBS and PN arise. It is important for patients with SBS to be referred to these specialty centers at an early point in the disease process to maximize access to treatment options and to facilitate appropriate long-term care.

Treatment

Nutrition therapy

- Diet modification is the foundation of therapy for patients with SBS.
- The primary goal of nutrition therapy is to prevent malnutrition and dehydration by maintaining adequate nutrient and fluid balance. A secondary goal of luminal nutrition is to promote bowel adaptation and improved absorption following extensive intestinal resection.
- Oral nutrients, enteral nutrition (EN), PN, or a combination of the three may be used depending upon the length and anatomy of remaining bowel and the patient's absorptive capacity.
- Patients with less than 100 cm jejunum–ileum to an end-enterostomy, less than 65 cm jejunum anastomosed to colon, or less than 30 cm jejunum–ileum anastomosed to colon likely will require long-term PN to maintain nutrient and fluid balance [22].
- Patients with preexisting malnutrition will require PN for 7 to 10 days following an extensive small bowel resection regardless of remaining anatomy and bowel lengths [23]. All attempts should be made thereafter to transition the patient onto an oral or enteral diet when stool output is less than 800 mL while the patient is taking nothing by mouth and when clinically feasible.

SBS without colon

- A low-residue, low-sugar diet of small, frequent meals with isotonic fluids sipped between meals generally is appropriate for SBS patients with an enterostomy in the postoperative setting.
- Patients with difficulty maintaining fluid balance should be instructed on the liberal use of salt and 1 to 2 L of ORS sipped between meals at this time.
- If poor fluid balance persists, the patient should be kept on intravenous normal saline hydration and nothing by mouth for 24 hours. Over the next 48 to 72 hours, the intravenous fluids should be slowly weaned off as small portions of appropriate foods and fluids are reintroduced with the goal of maintaining urine output of greater than 800 mL/d [24•].
- Within 4 to 6 weeks postresection, patients with an enterostomy should gradually resume eating fibrous foods and begin soluble fiber supplementation as tolerated to add bulk and to slow transit time through the remaining bowel.

SBS with colon

- Patients with SBS and a preserved colon may be advanced to a diet high in complex carbohydrates and low in fat, oxalates, and sugar shortly following resection. These patients will benefit from five to six small meals per day with isotonic or hypotonic beverages sipped between meals.
- The addition of soluble fiber can provide an additional source of energy and enhance sodium and water absorption in the remaining colon [25].
- A dietary oxalate restriction (wheat, berries, leafy greens, nuts, chocolate), along with an increase in calcium ingestion (2000 mg/d in divided doses) are instituted to reduce the risk of calcium oxalate nephrolithiasis in SBS patients with a large ileal resection and intact portion of colon [26].
- Neurologic symptoms of D-lactic acidosis may result from an excessive amount of readily fermentable, malabsorbed carbohydrates reaching the colon of SBS patients and precipitating the overgrowth of lactic acid-producing colonic bacteria. Treatment includes the restriction of dietary carbohydrates, especially simple sugars, and the regulation of intestinal flora through antibiotics and possibly L-lactate–producing probiotics [27,28].

EN in SBS

- Patients unable to consume adequate nutrition orally may benefit from EN infused at a slow rate into the bowel through a nasogastric feeding tube or a percutaneous endoscopic gastrostomy tube [29].
- A standard isotonic formula with intact protein, glucose polymers, and primarily long-chain fats generally is well tolerated and may have a favorable effect on bowel adaptation [30]. If a gradual advancement of polymeric feeds (in increments of 20 mL/h/d) leads to increased output, trial feeding with a semielemental, isotonic, peptide-based formula should be attempted [31].
- Enteral formulas with soluble fibers (eg, pectin, guar gum) and prebiotics (eg, fructooligosaccharides [FOS]) are proposed to enhance bowel adaptation and absorption; many standard and elemental enteral formulas are now available with added fiber and FOS [32].
- Fluid balance may be enhanced with the infusion of ORS through an enteral feeding tube by overnight continuous drip or by intermittent bolus as a replacement for the traditional water flush. Nauth et al. [33] described three SBS patients who were weaned off of PN by optimizing enteral fluid absorption through the use of nocturnal enteral rehydration.

PN in SBS

- Patients unable to maintain their weight near an ideal level with oral nutrition/EN and medical/surgical management alone will require PN to meet daily nutrient needs. Parenteral nutrient provisions should be initiated at 15 to 20 kcal/kg/d and 1.0 to 1.5 g protein/kg/d and advanced carefully as required to meet clinical goals of feeding.
- Patients demonstrating maintenance of nutrient status but unable to attain fluid balance considering GI, urine, and insensible losses will require intravenous hydration with a variable mix of electrolytes. In general, small bowel electrolyte losses can be replaced by using one half to full normal saline with 10 to 20 mEq potassium chloride/L, 25 to 30 mEq sodium acetate/L, 5 mEq calcium gluconate/L, and 5 to 10 mEq (1 g) magnesium sulfate/L [34].

Weaning off of PN

- Although SBS patients closely followed by specialized clinical care centers generally have good outcomes [35,36], the long-term use of HPN may lead to significant complications, including catheter-related sepsis and thrombosis, hepatic abnormalities, metabolic bone disease, large financial costs, and a reduced quality of life [37].
- Reducing PN provisions in SBS patients may occur safely upon weight stability or edema-free weight gain, positive daily enteral fluid balance of at least 500 mL, stable laboratory indices of renal function and nutritional status, and oral or enteral intake of at least 80% of estimated daily caloric needs [38].
- In a carefully conducted nutrient balance study, Jeppesen and Mortensen [39] found that SBS patients who absorbed less than one half of their daily intake were able to avoid the need for HPN through hyperphagia. However, hyperphagia may lead to increased losses in patients with less than 65 cm small bowel without colon. Those patients close to being weaned off of PN with average levels of intake should be encouraged to consume at least twice their basal metabolic rate as estimated by the Harris Benedict equations using actual weights [39].

Vitamin, mineral, and electrolyte replacement in SBS

- Micronutrient losses can be extensive depending upon which area of the bowel has been resected, and oral supplementation will be necessary, especially as the patient is weaned from PN.
- Many supplements are incompletely absorbed due to rapid transit, altered pH, and reduced endogenous production of factors enhancing absorption of micronutrients in the remaining bowel.
- Patients with SBS not receiving PN generally will require a multivitamin with minerals in chewable or liquid form in one to three divided doses daily. Calcium supplementation also is routinely administered in divided doses of 1000 to 3000 mg/d.
- Magnesium deficiency is common in patients with extensive stool or stoma output, and certain forms of oral magnesium replacement can further aggravate GI losses. Supplementation with magnesium lactate or gluconate taken 1 hour before meals and at bedtime in doses of 50 to 500 mg elemental magnesium daily may be best tolerated [26]. If oral repletion at maximum doses is not successful, intermittent intravenous magnesium sulfate (ie, 2 g magnesium sulfate biweekly) may be required in patients not routinely receiving PN or intravenous fluids [23].

- Losses of zinc can approximate 12 mg/L in small bowel effluent and 16 mg/L in stool output. In addition to the zinc provided through multivitamins with minerals, zinc sulfate may be administered for repletion in oral doses of up to 220 mg three times daily.
- Vitamin B_{12} absorption is interrupted in patients who have had greater than 60 cm of terminal ileum resected. Supplementation generally is administered by intramuscular injection of 300 to 1000 μg/mo.
- Deficiency of fat-soluble vitamins and essential fatty acids (EFAs) may occur in patients with severe fat malabsorption (secondary to an extensive ileal resection and/or bacterial overgrowth) and not receiving PN. Oral supplementation of fat-soluble vitamins can be administered individually (10,000 to 50,000 IU/d vitamin A, 400 to 1000 IU/d vitamin D) or as a whole in a water-miscible form (ie, ADEKs Pediatric Drops or Tablets [Axcan Pharma, Inc., Mont-Saint-Hilaire, Quebec, Canada]). Clinical signs of EFA deficiency include a triene/tetraene ratio of greater than 0.2; excessive hair loss; poor wound healing; dry, scaly skin unresponsive to water-miscible creams; and/or alterations in platelet function. One teaspoon of soybean or safflower oil may be taken three times daily to replace EFAs in patients not receiving PN. Cutaneous application of sunflower oil in doses of 2 to 3 mg/kg/d for up to 12 weeks may be necessary for repletion of EFAs in patients with persistent malabsorption or allergy to intravenous lipid emulsions [40].
- Routine monitoring of serum electrolytes (weekly to monthly), vitamins, trace minerals, and EFAs (every 3 to 6 months), as well as annual bone densitometry should be performed on all patients with SBS until stable.

Pharmacologic treatment

- The principal goals of drug therapy for SBS are to minimize GI symptomology and to maximize absorptive capacity with the purpose of attaining an optimal quality of life.
- For those patients with SBS and an underlying inflammatory bowel disease (IBD), it is important to treat the IBD and maintain remission to maximize absorptive potential.
- Antisecretory and antidiarrheal agents are considered first-line therapy for SBS, followed by pancreatic enzymes, bile acid therapy, antimicrobials, growth factors, and, potentially, probiotics. In general, if diarrhea is not improved symptomatically within 14 days at maximum dosage, control is unlikely with further use.
- Antimotility or antispasmodic agents reduce fecal urgency and discharge by relaxing the smooth muscle of the intestinal tract and decreasing contractility [41•]. Common antimotility agents used in SBS in order of increasing strength are loperamide, diphenoxylate/atropine, codeine, paregoric, and tincture of opium. Several antidiarrheals are available in both a pill form and a liquid elixir form that may contain sorbitol, a sugar alcohol known to cause diarrhea.

Loperamide (Imodium A-D; McNeil Consumer & Specialty Pharmaceuticals, Fort Washington, PA)

Standard dosage	Starting dosage: 2 mg orally 30 minutes before meals and at bedtime.
Contraindications	Infectious diarrhea, constipation, ileus, or obstruction. Should be discontinued if abdominal distention occurs. Monitoring for central nervous system (CNS) toxicity is indicated in patients with hepatic dysfunction.
Main drug interactions	No significant interactions.
Main side effects	Abdominal pain, distention.

Special points	The only antidiarrheal that is not sedative or addictive. Dosage may be safely increased in nonobstructive SBS to levels higher than 16 mg/d.
Cost effectiveness	Safe, easily accessible, and inexpensive. Should be used as first-line antidiarrheal therapy. Efficacy in lower doses may be poor in patients with high-volume diarrhea.

Diphenoxylate/atropine (Lomotil; Pfizer, Inc., New York, NY)

Standard dosage	Starting dosage: 1 tablet (2.5 mg diphenoxylate and 0.025 mg atropine) orally 30 minutes before meals and at bedtime.
Contraindications	Obstructive jaundice, infectious diarrhea. Not for use in children aged less than 2 years.
Main drug interactions	Known drug interactions include barbiturates, tranquilizers, and alcohol. May interact with monoamine oxidase (MAO) inhibitors.
Main side effects	Bloating, constipation, loss of appetite, severe stomach pain, nausea, and vomiting.
Special points	Is a Schedule V controlled substance and has the potential for addiction with higher doses. Patients with SBS should not exceed 16 tablets daily.
Cost effectiveness	Inexpensive. Similar efficacy to that of loperamide but with greater potential for adverse CNS events.

Codeine

Standard dosage	Codeine phosphate; acetaminophen and codeine phosphate (Tylenol with codeine No. 3; Ortho-McNeil, Fort Washington, PA). Starting dosage: 15 mg (one-half tablet) orally 30 minutes before meals and at bedtime.
Contraindications	Significant respiratory depression (in unmonitored settings), acute or severe bronchial asthma, hypercapnia, paralytic ileus. Should be used with caution in elderly or debilitated patients and in patients with alcoholic liver disease, hypotension, adrenocortical insufficiency, thyroid disorders, prostatic hyperplasia, urethral stricture, seizure disorder, CNS depression, head injury, or increased intracranial pressure. Safety and efficacy in pediatric patients have not been established.
Main drug interactions	May increase toxicity of CNS depressants, tricyclic antidepressants, or MAO inhibitors (may also decrease blood pressure). May enhance effect of warfarin.
Main side effects	Lightheadedness, dizziness, sedation, nausea, vomiting, and dyspnea.
Special points	Causes sedation; caution must be used in performing tasks that require alertness. Tolerance or drug dependence may result from extended use.
Cost effectiveness	Inexpensive. Similar efficacy but greater potential for adverse effects compared with loperamide.

Paregoric, USP and opium tincture

Standard dosage	Opium tincture (50 mg morphine per 5 mL) is 25 times more concentrated than paregoric (2 mg morphine per 5 mL). Starting dosage for paregoric (camphorated opium tincture): 5 mL orally 30 minutes before meals and at bedtime. Starting dosage for opium tincture (deodorized opium tincture): 0.3 to 0.6 mL (5 to 10 drops) orally 30 minutes before meals and at bedtime.
Contraindications	Increased intracranial pressure, severe respiratory depression, severe hepatic or renal insufficiency, or near-term pregnancy.
Main drug interactions	May increase toxicity of CNS depressants and MAO inhibitors. Tricyclic antidepressants may potentiate the effects of opiate agonists. Dextroamphetamine may enhance the analgesic effect of opiate agonists.
Main side effects	Drowsiness, dizziness, confusion, decreased urination, visual disturbances, bradycardia, hypotension, headaches, nausea, and vomiting.

Special points	Opiate agonists reduce diarrhea by inhibiting GI motility and diminishing GI secretions. Opium tincture is a Schedule II controlled substance, whereas paregoric is a Schedule III controlled substance; both have the potential for addiction at higher doses and with prolonged use.
Cost effectiveness	Usually highly effective in reducing diarrhea associated with SBS. Due to potential adverse effects, use of opium should be reserved for patients who have failed therapy with other antidiarrheals; dosage should be gradually titrated upward to point of efficacy without side effect.

Antisecretory/gastric acid-reducing agents

- Antisecretory or gastric acid-reducing agents such as H2Bs and PPIs may decrease the severity of the secretory diarrhea commonly seen in the postoperative phase of SBS. PPIs often are preferred over H2Bs due to a more sustained effect and more convenient oral dosing (generally once daily) [40]. PPIs cannot be added directly to a PN solution, whereas certain H2Bs, such as famotidine, commonly are added to PN. The activity of PPIs may be reduced with concurrent administration of H2Bs [41•].

H2Bs

Standard dosage	Famotidine (Pepcid; Merck & Co., Inc., Whitehouse Station, NJ): 20 mg orally twice daily before meals or 40 mg daily via PN.
Contraindications	None other than known hypersensitivity.
Main drug interactions	Unlike cimetidine and ranitidine, famotidine does not appear to inhibit the metabolism of certain drugs, including warfarin, theophylline, phenytoin, diazepam, or procainamide.
Main side effects	Generally well tolerated.
Special points	Psychiatric disturbances have been reported in patients receiving parenteral famotidine, and discontinuation may be necessary in the absence of any other potential cause.
Cost effectiveness	Inexpensive. Other H2Bs or PPIs also can be used.

PPIs

Standard dosage	Omeprazole (Prilosec; AstraZeneca International, Wilmington, DE): 20 mg orally once or twice daily prior to meals. Lansoprazole (Prevacid; TAP Pharmaceutical Products, Inc., Lake Forest, IL): 15 to 30 mg orally once or twice daily prior to meals. Esomeprazole (Nexium; AstraZeneca International, Wilmington, DE): 20 to 40 mg orally once or twice daily at least 1 hour before a meal.
Contraindications	None other than known hypersensitivity. Reduced dosages may be necessary for patients with severe hepatic impairment.
Main drug interactions	May prolong elimination of diazepam, warfarin, and phenytoin. May decrease absorption of itraconazole and ketoconazole, some protease inhibitors, and oral iron salts. May increase circulating levels of benzodiazepines and carbamazepine.
Main side effects	Headache and flatulence.
Special points	The most effective doses of PPIs in hypersecretory conditions such as SBS have not been studied. As primary absorption of PPIs takes place in the small intestine, patients with SBS may require higher doses to achieve adequate clinical responses.
Cost effectiveness	Expensive. Higher doses often are necessary in the treatment of SBS.

Octreotide

Standard dosage	Octreotide acetate (Sandostatin; Novartis Pharmaceuticals Corp., East Hanover, NJ): 100 to 300 μg injected subcutaneously three times daily, or 300 to 900 μg daily via PN. Patients who have responded well to at

	least 2 weeks of the subcutaneous injection may transition to the long-acting formulation (Sandostatin LAR; Novartis Pharmaceuticals Corp., East Hanover, NJ) at an initial dosage of 20 mg intramuscularly monthly. Dosage of the long-acting formulation may be increased to a maximum of 30 mg intramuscularly twice monthly as needed.
Contraindications	Known hypersensitivity to drug.
Main drug interactions	May decrease drug absorption. Concomitant administration of Sandostatin with cyclosporine may decrease blood levels of cyclosporine and result in transplant rejection.
Main side effects	Biliary abnormalities (cholelithiasis, sludge, dilatation), GI disturbances (nausea, vomiting, diarrhea, steatorrhea, abdominal discomfort, bloating, and flatulence), hyperglycemia and abnormal glucose tolerance, sinus bradycardia, injection site pain, and respiratory distress (dyspnea, upper respiratory infection, and flu-like symptoms). GI side effects generally resolve after continued use.
Special points	Suppresses gastric and pancreatic secretions and inhibits GI motility and splanchnic blood flow. Also suppresses the endogenous secretion of GH and/or insulin-like growth factor I to thereby potentially reverse or delay bowel adaptation in SBS.
Cost effectiveness	Expensive. Often effective in reducing large-volume secretory diarrhea and decreasing fluid and electrolyte requirements in patients with proximal enterostomies.

Clonidine

Standard dosage	Clonidine hydrochloride (Catapres; Boehringer Ingelheim, Ingelheim, Germany). Starting dosage: 0.025 mg orally twice daily. Dose may be increased weekly to a maximum of 0.2 mg orally twice daily. Gradual withdrawal is necessary if the drug is to be stopped.
Contraindications	Should be used with caution in patients with severe coronary insufficiency, conduction disturbances, recent myocardial infarction or cerebrovascular accident, chronic renal insufficiency, sinus node dysfunction, or existing CNS depression.
Main drug interactions	Antagonized by tricyclic antidepressants; potentiates CNS depressants.
Main side effects	Dry mouth, drowsiness, dizziness, weakness, constipation, rash, myalgia, urticaria, nausea, insomnia, agitation, orthostatic hypotension, or arrhythmias.
Special points	An α2-adrenergic receptor agonist that may reduce diarrhea by increasing sodium and water absorption and by decreasing bicarbonate secretion. Is most commonly used to treat hypertension.
Cost effectiveness	Inexpensive to moderately expensive depending on use of generic versus commercial brand. Efficacy has not yet been demonstrated with a controlled clinical trial in SBS patients.

Bile acid sequestrants

Standard dosage	Cholestyramine (Questran; Bristol-Myers Squibb, Cincinnati, OH) is administered in 2- to 4-g dose in water or juice just before meals three times daily. Colestipol hydrochloride (Colestid; Pfizer, Inc., New York, NY) is administered in granule form in 5-g dose one to four times daily (maximum 30 g/d) and in tablet form as 2 g one to four times daily (maximum 16 g/d).
Contraindications	Complete biliary obstruction or bowel obstruction.
Main drug interactions	May bind other drugs if administered simultaneously. Other drugs should be taken several hours before or after bile acid sequestrants.
Main side effects	Constipation, heartburn, nausea, vomiting, stomach pain. GI side effects generally resolve after continued use.

Special points	Binds with bile acids to form an insoluble complex that is eliminated in feces without irritation of the colonic mucosa. Should be used only in patients with limited (< 100 cm) ileal resection and some portion of colon in continuity. May interfere with absorption of fat-soluble vitamins, folic acid, calcium, and iron.
Cost effectiveness	Moderately expensive. Efficacy is limited to a specific patient population as mentioned, and misuse may aggravate diarrhea and malabsorption in SBS.

Pancreatic enzyme therapy

Standard dosage	Pancrelipase (Creon; Solvay Pharmaceuticals, Inc., Marietta, GA; Lipram; Global Pharmaceuticals, Philadelphia, PA; Pancrease; Janssen-Cilag, Titusville, NJ; Panokase; Breckenridge Pharamceutical, Inc., Boca Raton, FL; Ultrase; Axcan Pharma, Inc., Mont-Saint-Hilaire, Quebec, Canada; Viokase; Axcan Pharma, Inc., Mont-Saint-Hilaire, Quebec, Canada). A dose of 4000 to 48,000 U of lipase (one to six tablets or capsules) should be taken with meals and with snacks.
Contraindications	Known sensitivity to hog protein (pork). Acute pancreatitis or acute exacerbation of chronic pancreatitis.
Main drug interactions	May impair absorption of oral iron and folic acid.
Main side effects	Generally is free of adverse effects. Nausea, cramping, and/or diarrhea may occur with excessive dosage.
Special points	Adequate gastric acid-reducing agents should be prescribed with use of pancreatic enzymes, as pancrelipase is partially inactivated by gastric juice.
Cost effectiveness	Moderately expensive depending on brand used. Least effective in hypersecretory states.

Antibiotics

Metronidazole

Standard dosage	Flagyl (G.D. Searle, LLC, Chicago, IL): 250 mg orally three times daily.
Contraindications	Hypersensitivity to metronidazole or other nitroimidazole derivatives. Caution should be used in pregnancy, and dosage should be reduced in patients with severe liver impairment, CNS disease, or severe renal failure.
Main drug interactions	May potentiate oral anticoagulants, phenytoin, lithium. May impair phenytoin clearance. Concurrent use with cisapride should be avoided. Potentiated by cimetidine.
Main side effects	Metallic taste, disulfiram-like reaction, nausea, vomiting, hepatotoxicity, and, rarely, seizures. Potentially reversible peripheral neuropathy has been reported and may be associated with prolonged use of high-dose metronidazole.
Special points	Generally, metronidazole would be first-line therapy in patients with SIBO and SBS. Patients who do not maintain response to a single 7- to 10-day course may require either repeated (first 7 to 10 days of every month) or continuous courses of rotating antibiotic regimens to prevent resistance [42].
Cost effectiveness	Inexpensive and generally effective.

Ciprofloxacin

Standard dosage	Cipro (Bayer Corp., West Haven, CT): 250 mg orally twice daily.
Contraindications	Hypersensitivity to ciprofloxacin or other quinolones. Concurrent administration with tizanidine.
Main drug interactions	Increases theophylline levels. Concurrent administration with dairy products or calcium-fortified juices, most antacids, oral electrolyte supplements, and sucralfate should be avoided (should be taken 2 hours before or 6 hours after). May increase the effect of glyburide. May increase

	serum caffeine levels if taken with caffeine. Should not be administered with enteral feedings.
Main side effects	Diarrhea, hepatotoxicity, headache, dizziness, rash, eosinophilia, tendonitis.
Cost effectiveness	Moderately expensive.

Rifaximin

Standard dosage	Xifaxan (Salix Pharmaceuticals, Inc., Morrisville, NC): 200 mg orally three times daily. May take up to 1200 mg/d.
Contraindications	Should not be used if diarrhea is accompanied by fever or blood in stool. Not recommended for use in children.
Main drug interactions	None.
Main side effects	Headache, pseudomembranous colitis.
Cost effectiveness	Moderately expensive, yet generally tolerated better than other antibiotics.

Recombinant human growth hormone

Standard dosage	Somatropin (Zorbtive; Serono, Geneva, Switzerland): once-daily subcutaneous injection of 0.1 mg/kg/d (not to exceed 8 mg/d) for 28 days.
Contraindications	Should not be used in patients who are critically ill, respirator dependent, awaiting open heart or abdominal surgery, or diagnosed with and undergoing treatment for cancer. Should be used with caution in patients with uncontrolled diabetes, high blood pressure, carpal tunnel syndrome, or history of cancer.
Main drug interactions	None.
Main side effects	Myalgias, arthralgias, swelling, injection site irritation or pain, glucose intolerance, nausea, vomiting, abdominal pain, and gas.
Cost effectiveness	Very expensive. Worth attempting in appropriate patients following an optimal diet and medication regimen but still unable to wean off of PN [43].

Surgical therapy

- Surgical therapy for SBS may be divided into strategies to restore intestinal continuity (takedown enterostomy), relieve obstruction and dysmotility (strictureplasty or bowel tapering), lengthen remaining intestine (Bianchi procedure or STEP technique), prolong transit (reversed intestinal segments, colonic interposition, or creation of artificial sphincters), and transplant new intestine [44••].
- Collective surgical attempts to enhance bowel adaptation using imaginative manipulation of the patient's residual bowel are known as autologous GI reconstruction [45]. The bowel lengthening and tapering techniques have been used primarily in children, whereas the reversal of intestinal segments has been done primarily in adults.

Restoration of intestinal continuity

Standard procedure	Takedown of enterostomy and reconnection with remaining colon or takedown of previously bypassed bowel.
Complications	Leak due to anastomotic dehiscence or perforation. Depending on the length of time bypassed bowel has been maintained out of continuity, the bowel restored to continuity can be defunctionalized and may require time to resume absorptive function.
Special points	Although all remaining bowel should be placed back into continuity whenever feasible in SBS, the decision to restore bowel continuity is made on an individual basis depending upon length of the intestinal remnant and the patient's overall condition [44••].

Bowel tapering

Standard procedure	Can be performed through resection or plication. Resection involves longitudinal transection with excision of a portion of the bowel lumen along the antimesenteric border done by using a surgical stapling device or by hand suturing. Plication is a simple infolding and overlapping of the dilated bowel with a running suture, having the advantage of maintaining small bowel surface area.
Complications	Plication has the tendency to break down and unravel at the suture line with redilation or obstruction due to extensive infolding. Tapering through resection runs a higher risk for leak due to excision of a portion of the bowel wall.
Special points	Stasis may be reduced by reestablishing propulsion during contraction of the bowel wall. Indicated only for patients who have sufficient absorptive bowel length but with focal or extensive bowel dilatation leading to symptomatic bacterial overgrowth or recurrent sepsis [46].

Bianchi procedure

Standard procedure	Division of dilated bowel longitudinally along the mesenteric and antimesenteric borders with preservation of the blood supply to two divided propulsive segments. The two parallel segments then are anastomosed isoperistaltically and to the colon to create a segment of bowel with half the diameter and twice the length of the original segment.
Complications	Stenosis at the segmental anastomosis, intersegmental fistulae, loss of a segment due to necrosis, anastomotic leak, or recurrent dilation.
Special points	Indications: a short segment of remaining bowel (< 10% with ileocecal valve or 10% to 20% without ileocecal valve) and segmental dilation without mesenteric thickening [18]. Benefits: preservation of absorptive surface area, improved absorption with potential weaning of PN, and possible return of normal liver function. May offer a bridge to transplantation in cases of progressive liver failure at high risk for death with prolonged waiting for transplantation [18].

STEP technique

Standard procedure	Serial transverse linear stapling of the dilated bowel from opposite directions to divide the bowel transversely from the mesenteric and antimesenteric sides. Reduces bowel diameter, lengthens bowel, and promotes peristalsis without loss of surface area.
Complications	Redilation of the STEP segment; possible bowel obstruction, abscess, or hematoma. Fewer potential complications than for the Bianchi technique due to avoidance of the need for dissection or anastomosis and because staple lines are discontinuous.
Special points	Limited outcome data are available at this time, but results are encouraging. Marked dilatation is required to achieve clinically significant lengthening [44••].

Reversal of intestinal segments

Standard procedure	Surgical reversal of short segments of jejunum or ileum to create antiperistaltic segments that delay passage of fluid, electrolytes, and nutrients sufficiently for increased absorption. Segments should be placed just proximal to the small bowel–colonic junction and range in length from 3 to 10 cm.
Complications	Transient obstructive symptoms and anastomotic leak.
Special points	Long-term benefit has been demonstrated in very few patients; however, most patients who have undergone this procedure also were diagnosed with an IBD.

Colonic interposition

Standard procedure	Insertion of a partial colonic segment (8 to 24 cm) in an isoperistaltic prejejunal or antiperistaltic preileal fashion.
Complications	Dilatation and enterocolitis within the transposed segment of colon.
Special points	May slow the rate of delivery of nutrients to the distal small bowel and thereby improve absorption of nutrients, fluids, and electrolytes in SBS. Potentially useful, either as an isolated procedure or combined with other bowel reconstructive efforts, for patients with sufficient absorptive mucosa but rapid transit.

Creation of artificial sphincters

Standard procedure	Most frequently used technique involves the formation of an intussusception valve to increase intraluminal pressure. May require the sacrifice of significant lengths of valuable small bowel to construct valve [45].
Complications	Bowel obstruction, dilatation of the proximal intestine, stasis, valve necrosis, and intussusception at the site of the valve, all of which may lead to need for valve removal.
Special points	Proposed to reduce hyperacidity, delay small bowel transit, and prevent retrograde reflux of colonic contents into the small bowel. Inconsistent reports of increased absorptive capacity and extended survival have been noted [44••].

Small bowel transplantation

Standard procedure	Insertion of a healthy small intestine from a living or cadaver donor into a patient with SBS. May require surgical removal of a section of diseased small intestine.
Complications	Allograft rejection and potential loss, bowel necrosis, anastomotic leak, wound dehiscence, stomal dehiscence, persistent malabsorption with fluid and electrolyte imbalance, neurotoxicity, interstitial edema with ventilator dependency, renal insufficiency, bacteremia, catheter-related sepsis, intra-abdominal abscess, peritonitis, abdominal wound infection, death [47,48].
Special points	Medicare-approved indications for referral of patients to small bowel transplantation include irreversible intestinal failure with development of progressive PNALD, loss of more than 50% of major venous access sites for provision of PN, recurrent severe catheter-related sepsis, and impaired renal function due to massive GI fluid losses [20]. Other indications for referral include locally aggressive, nonmetastasizing desmoid tumors removable only through massive evisceration and total intestinal aganglionosis or microvillus inclusion disease in infants [20].

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